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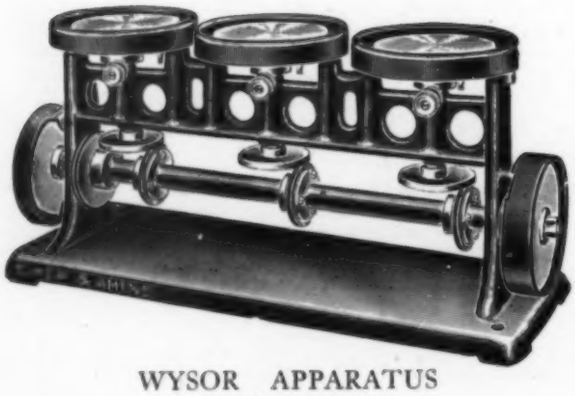

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CHEMICAL & METALLURGICAL ENGINEERING

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Proving An Obsession

SENATOR KING, attacking the American dye industry, apparently bases his major charge upon the assumption that there is a monopoly in the American business. He cites as evidence the two great producers of organic chemicals in the United States, the du Pont and the Allied Chemical & Dye organizations. It is absurd on the face of it to charge monopoly when there are two or more great competing groups of industrial interests. These two the Senator admits; and if he were better advised regarding the business, he would know of other well-established active competitors of these two corporations. It is little but an obsession on the part of a vigorous opponent of the industry which brings forth such a charge.

This position of Senator KING is perhaps the most favorable one which he could have taken. In any event it gives a splendid opportunity for developing the real economic and industrial side of the case, as well as the technical problems involved.

In striking contrast to this attitude of the Senator is the very frank response which the principal representatives of the chemical industries are making before the investigating committee. Mr. GARVAN has promised on behalf of the Chemical Foundation and others that every document or needed person will be at the service of the committee without subpœna. The industry and its representatives know well that a thorough public presentation of the facts, not only of dye manufacture but also of dye import, cannot be harmful to the American industry. It is fortunate, indeed, that a frank spirit is thus made evident at the very start of the investigation.

Helium and The Roma Disaster

DOUBTLESS many lessons are to be drawn from the disaster that overtook the Roma and brought death to thirty-four persons engaged in the development and operation of lighter-than-air craft. The lack of helium has been blamed for much of the trouble, probably too much, although it should have been used in this ship. And the United States can no longer be held guiltless if it continues to permit training in the lighter-than-air service in hydrogen-filled bags. We have the helium—2,300,000 cu.ft. of it—or more than twice enough to have filled the Roma. It has been alleged that helium was not used because the Roma was an old ship with leaky fabric, from which the precious helium would have escaped. By what curious distortion of values does the government place helium above the lives of those who are "merely in training"?

Of course we realize that helium would not mitigate all the dangers of lighter-than-air travel and that mechanical failures have been primarily responsible for the terrible disasters that overtook the ZR-2 and the Roma. But in both cases death and destruction due to fire would not have occurred had there been a non-flammable gas in the bags. A sane program for our lighter-than-air service will abandon training in second-hand ships filled with hydrogen. It will provide for the use of helium even in training. And finally it will grant the Bureau of Mines sufficient money and talent to make the necessary fundamental scientific studies on helium and for the ultimate erection of plants for the recovery of the gas.

The recent disasters point to the necessity of recovering helium not only for the conservation of a natural resource but as a measure of humanity in safeguarding those who are devoting their lives to the conquest of the air. Let's have no more disasters in which a flammable gas adds horror to a mechanical failure. We may not be able to foresee the break of a rudder or the buckling of a frame member, but we do know that hydrogen will burn and that it is likely to take fire in almost any disaster that can overtake a lighter-than-air ship.

A German Chemist's View Of Conditions in America

THERE has lately been sent to us a reprint of an address made by an eminent German chemist who spent a considerable number of years in the United States but who returned to Germany before the war and settled down there as managing director of an important chemical enterprise. Last year he visited this country for the first time in 13 years, and he gave his impressions in November at a meeting of the "Verein zur Wahrung der Interessen der chemischen Industrie Deutschlands." He is a typical German of the cultivated class in industry; competent, able and faithful to his obligations as he sees them. He speaks English fluently.

He confirms his earlier impressions of the United States as the land of great contrasts, or, more correctly said, of great antitheses. He is impressed with the vast number of automobiles, with the high wages that are still paid, with the number of men out of work and the threats of collision between labor and capital. He draws an interesting comparison between the efficiency with which HENRY HOWARD, a chemist, trained officers for the mercantile marine, and the débâcle of American shipping that has followed the Armistice. Prohibition comes in for extended discussion, and from this he proceeds to an observation made by a chauffeur on a trip from Niagara Falls to Buffalo. At the time a plebiscite was about to be taken as to whether or not Niagara Falls should adopt the commission form of government, and billboards were plastered with arguments pro and con. He asked his chauffeur if he favored the commission form. "No," said he, "I'm against it. They all steal from the city; formerly there were thirteen who got the pickings, and now they propose to reduce the

number to five. I'm in favor of letting as many as possible get something out of it." That was abundant evidence for the German mind. "I could offer nothing against this argument," said the speaker. "I held my peace and thought of the former conditions bei uns in Deutschland, of the blessings that democracy has brought us already, and of what it has yet to vouchsafe us." From a former dyed-in-the-wool Prussian Royalist, that observation about the blessings of democracy seems a little strained, but maybe it was not.

Of greater interest are his comments on the friendly disposition of Americans toward Germany and Germans. He takes pleasure in announcing that *this grows in favor as their relations with England and France grow worse*. He cautioned his hearers, however, to avoid any awkwardness in *aiding such convalescence* (Gesundungsprocess) but rather to await its natural development. There speaks your true German! The willingness, the desire, to profit by ill-will and hatred among others remain, but wisdom counsels caution as to the methods.

It is worth while to pause right at this point lest we fall into hypocrisy. The Gospel of Hate was indeed the very shibboleth of the old German Foreign Office. To foment strife among others is the easiest way to conquer them. It is also very practical. There is no question that it has been for many years the German method. It is terribly destructive and harmful, but at the same time very profitable. Until, however, we can feel ourselves wholly free from the practice it is best not to get angry over it. Our business is to resist the lure and to make the best we can of things as they are. To do this is no angelic virtue; it is merely being decent in bad times.

A curious chapter has to do with the persistent German obsession about British control of American newspapers. Lord NORTHCLIFFE'S "influence" over twenty-seven daily publications is demonstrated by his cable news connections, and the speaker learned from "authority" that while the New York *Times* paid only 3½ cents a pound for Canadian paper "the well-known owner of the New York *American*, HEARST, the paper for the by him controlled 19 Zeitungen only at 13 cents the pound could buy. His refusal, himself into the service of the Entente to place, must have cost him $11,000,000 during the war, whereas the *Times* saved every year $360,000 on the cost of paper." The quotation, which for prudential reasons we have made as literal as possible, carries the suggestion that NORTHCLIFFE controls the Canadian paper manufacturers who refuse to sell to HEARST.

The speaker waxed very warm in his denunciation of the confiscation of German chemical patents and was persuaded that this "theft" would in time be made good, either to the former owners of the patents or by the United States Government to that of Germany.

The automobile works of HENRY FORD made a deep impression and the fundamental principle that "The laborer never waits for work, but the work always waits for the workman" is one which he commends to German manufacturers. He noted also in the power plant that with each electric generator there is coupled a two-cylinder gas engine that works at full load together with a tandem compound steam engine that meets the peaks and valleys.

He was not hopeful of a favorable revision of the tariff for German goods, especially German-made chemicals. Despite the disadvantages of high wages and prices, he thought that in this respect, as indeed often occurs, absurdity (Unvernunft) would remain the victor.

Patience, Patience, And Then More Patience

A REPORT of 1919, lately published in the *Journal of Commerce and Commercial Bulletin* of New York, estimated the loss to labor through strikes during the year at $750,000,000, and the loss to industries as $1,250,000,000, all right here in the United States.

The majority of strikes are called by men in occupations that can scarcely be designated as trades. A job that may be learned in a week or in a day or so or in a forenoon is not a trade. That is manual labor that does not require thinking to perform. It is the kind of work into which those men and women drift who are feeble of mind or will. They weigh a great deal when they go out on strike because they are parts of an organized whole, but they could all be replaced without much interruption by other willing workers. Indeed in most cases the output would be increased by *willing* workers. They are entirely different from skilled mechanics, who also strike, but who usually do so for a definite purpose. Skilled mechanics plan their walk-out carefully, and they know what they want. Usually they keep their agreements. The unskilled, however, so far as a vast number of their members are concerned, follow out like sheep. They don't think, because they can't. They can't co-ordinate. Like the student K of whom we told lately, they have a mental age of 10 or 12 years. What they call thinking is being led. "I made up my mind to walk out," says one, when he did not make up his mind at all. He means that his tropisms were responsive to the stimulus. He couldn't help going on strike.

These mental children are scarcely to be blamed for breaking their agreements. We do not hold a child of 10 or 12 to a signed contract. Why should we make an infantile striker's muscles and his long pants responsible for what he has not got in his head?

Somehow, some way, some new approach must be discovered. There's no use in fooling ourselves with the belief that the mentally undeveloped are the same as other men. They do not constitute the whole of unskilled labor, and even among those that appear hopelessly stupid there are those who may have undeveloped resources, that if aroused, would place them, in one or more single respects, far beyond the rest of us. CLAUDE LORRAINE was held to be a half-wit until one day he took a canvas and some of his master's brushes and paints along with him and came back with a picture. After that Cardinals and Princes pressed for admission to his studio. We do not know what the fraction is of the undeveloped or moron class. We know they are there, however, and that they do not and cannot understand the nature of an obligation. If they commit perjury, they are like a child who thinks itself immune because it has its fingers crossed.

They are entitled to life, liberty and the pursuit of happiness. But they should be known and placed in yard gangs or at work of a sort that will not land them into positions of trust and responsibility by virtue of seniority. If they organize into unions, they should not be permitted to strike save under the approval of some senior body or committee or organization that requires mental responsibility and character for its membership. Maybe the psychologists will help out some day. As it is, the situation is as though we were to ask a child to leave its maypole dance and come over to steer a ship.

A Plea for Chemical Economics

IN HIS ADDRESS at the International Meeting of Chemical Societies in the Great Hall of City College last September, Sir WILLIAM POPE urged chemists to bear in mind that there is great wealth yet to be obtained from the soil. Nature has a way of working silently, without coal consumption—that is, without requiring coal from the mines—and without charging for time by the hour. She synthesizes according to local conditions. Not only do plants grow and secrete exactly what we want, but micro-organisms are available to do far more than to produce alcohol and carbon dioxide. These also work 24 hours a day and they know just what they need to complete their cycle of existence, whereby we may profit. Professor HIBBERT of Yale has long been urging the slogan, "Let the Microbes Do Your Work for You!" Lately Dr. E. J. RUSSELL of Rothamsted has written of "Soil Conditions and Plant Growth" in a Rothamsted monograph published by Longmans, Green & Co., of London. His observations on conditions affecting plant growth are reported to be of wide general interest.

Our readers may recall an incident that occurred several years ago. A Mr. ECKERT, who was manager of a sugar plantation in Hawaii, was troubled by weeds. The rainfall is especially heavy there. The cost of labor in weeding ate up the profits. He bethought himself that the young sprouts of sugar cane were sharp and stiff, whereas the weeds were not. He softened roofing felt with caustic soda, laid it over the young sprouts, which pierced through or buckled under, making a visible hump which could be easily cut through later on. The weeds curled up and died. He saved 75 per cent of his labor costs and got 25 per cent better crop by it. Then he came on to Dr. LITTLE and got him to work out a soft, easily piercable bagasse felt, which served in the place of the building felt. Then he put up a paper mill for his company in Hawaii—and the outfit works very successfully. Mr. ECKERT patented his invention.

Sir WILLIAM wondered whether, if the same measure of scholarly and intelligent study had been addressed to the production of indigo from natural sources as was given to the synthesis of the product from coal tar, the artificial product would have replaced that produced on plantations properly administered. The beet-sugar industry worries along under tariff protection which it always needs, but has the last word been said in regard to sugar beets? Has the maximum been reached in growing sugar cane? Have we exhausted the product of sumac? What is the cheapest source, besides molasses, for the production of ethyl alcohol? Will it come from the intensive production of corn, and if so, what kind of corn? Where is the incidence of diminishing returns in the intensive growing of corn? What are the possibilities of cassava? How about a strain of potatoes more abundant in starch, irrespective of its eating qualities?

Industry is constantly providing new solvents. What are we doing with them in relation to natural products?

These are questions in chemical economics and the answers are not available, because we neglect chemical economics. The reason is, we do not fit ourselves to take a comprehensive view. What is needed is more co-ordination among chemical engineers and biochemists and botanists, all working together, understanding one another, and using the same scientific language in discourse. It is time for chemists to quit playing on a fiddle with one string, whether that string be organic or colloidal or metallurgical or biochemical or what not. We recommend to the American Chemical Society a committee on co-ordination which shall have for its purpose the bringing of specialized chemists out of their ruts. The great merit of the Society is the multiplicity of its divisions and sections. Why not mix 'em up? It would be a good thing all around.

What Does the Steel Recovery Mean?

AFTER extensive liquidation of stocks of steel in the hands of steel buyers, and of manufactures of steel in the hands of makers and distributors, a liquidation that was claimed to have been practically completed by the beginning of last October, the rate of steel ingot production rose to a rate of 23,000,000 tons in October and November, declining to a rate of 16,000,000 or 17,000,000 tons in the last week of December.

Now we have a remarkable fact, that the rate of steel ingot production has risen, in approximately 2 months, to about 29,000,000 tons a year. That is a fact. What does it mean?

To account for this rise in steel production in such a short space of time one might refer to the fact that production of steel ingots in July, 1921, was at the rate of only about 11,000,000 tons a year, while in the first 9 months of 1920 the rate had fluctuated but little from an average of 42,000,000 tons a year. The one rate was scarcely more than one-fourth of the previous rate. The extremity of the decline was explained on the ground that consumers were using up stocks. However, if that suggests an explanation to the recent rise, there is an admission that buyers of steel have been replenishing stocks lately, which is denied by both parties.

Is the steel industry overbuilt or not? Most observers claim it is. The capacity in ingots is between 50,000,000 and 55,000,000 tons a year, this being indicated by taking the actual production in 1916 and allowing for increases since, the estimate being supported by the fact that when greatly handicapped by various physical disabilities the industry produced during the first 9 months of 1920 at the rate of 42,000,000 tons a year. The capacity is fully double that of 1910, when a production of 25,000,000 tons kept domestic consumers quite busy working up the steel and allowed a considerable tonnage to be exported.

Against the contention that the steel industry is overbuilt it is urged in some quarters that an excess capacity over normal requirements is needed to carry the peak load. This sounds nice in theory except for the expense of carrying the extra capital investment and the difficulty in finding labor when men are busy consuming steel, but it presents an awkward situation when one recalls that before the war steel producers used to say it was impossible to advance prices unless the industry was operating at not under 80 or 85 per cent of capacity, while present prices are claimed to be far below cost of production and in some cases to be no more than cost less overhead. An industry is not very well fixed if it can get its prices only up to cost when running at peak load.

If the steel industry is overbuilt and the buying in the past few weeks has represented actual consuming requirements, business in the United States is in very fair condition indeed, even if the steel industry is not. A few weeks' time will tell, in all probability, what the actual condition is in steel with respect to business in general.

Italian Chemical Industries

FROM OUR SPECIAL CORRESPONDENT

GENOA, ITALY, Feb. 7, 1922.

JANUARY was a very difficult month for the Italian chemical industry owing to the following economic factors: (1) Suspension in the payments of a large bank, (2) the continued scarcity of electric power, (3) a considerable fall in the foreign exchange, and (4) a reduction in the demand, as well as lower prices, especially for the commoner products and fertilizers. The coming spring will, however, improve matters because the exhaustion of stocks in many quarters will necessitate the production of goods of all sorts.

SULPHUR INDUSTRY

In order to avoid the damaging of crops on the isle of Sicily through the continued action of sulphur-dioxide fumes, the Italian Government issued special regulations requiring that the burning of sulphur on this island, or elsewhere, be conducted at least 100 meters from cultivated properties, and that all possible precautions be observed for avoiding atmospheric pollution. The sulphur mines continued their campaign for reducing manufacturing costs of crude sulphur, pointing out that the deficient means of transportation between the mines and the coast resulted in freight rates as high as 100 lire per ton. The necessity of developing the water power and increasing the number and capacity of the hydro-electric plants was urged as a relief for this situation. A further reduction in the prices of the different sulphur products was noted, owing to the scarcity of demand on the part of Italian and foreign clients.

TARTARIC ACID AND TARTAR MATERIALS

Italian tartaric acid and cream of tartar producers brought forward a motion to the Italian Chamber, insisting on the application of a much higher export tax on raw tartar, pointing out that the present price permitted foreign manufacturers to produce the finished tartar products cheaper than is possible in Italy, due to the high cost of Italian labor, transportation and coal.

The largest works producing tartaric acid and tartrates have their headquarters at Agnano, Barletta, Milan and Casale. An export tax of 22.50 lire per ton was placed on raw tartar for assisting the development of the manufacturing industry before the war, being raised recently to 50 lire (10 gold lire). An export tax of 100 lire (20 gold lire) is now proposed in the case of raw materials containing up to 50 per cent of potassium bitartrate, and of 160 lire (32 gold lire) in the case of raw materials containing more than 50 per cent of this compound.

During the first 6 months of 1921 the exports of raw tartar reached 1,268 tons, as compared with 4,467 tons in 1920 and 1,724 tons in 1919 during the corresponding period; the countries of exportation being France, Germany, England, Holland, Switzerland and the United States, this last country being the most important importer of raw tartar (650 tons). The imports reached 29 tons, against 91 tons in 1920 and 2 tons in 1919.

The higher prices demanded by Italian producers of tartaric acid brought a marked reduction in the exportation of this product. During the first 6 months of 1921 only 834 tons was exported, compared with 1,415 tons in 1920 and 633 tons in 1919 during the same months. The exports of cream of tartar were also reduced, reaching 325 tons, against 355 tons in 1920 and 103 tons in 1919. The imports of cream of tartar reached only 3 tons, against 4½ tons in 1920 and 4 tons in 1919.

COPPER SULPHATE

The production of copper sulphate, which reached 101,000 tons in 1918, has since continued good, and would certainly have been greater if there had not been difficulty in getting raw materials. To alleviate the situation the producers demanded repeatedly from the Italian Government that they be given some of the copper left over from the war, and after some delay they obtained 1,000 tons of this, and 20,000 tons was delivered to the state railways for electrification purposes.

The exportation of copper sulphate increased conforeign products. During the first half of the past year 2,476 tons, against 4,116 tons in 1920 and 800 tons in 1919 during the same period of time. The importations reached only 598 tons during 1921, 791 tons during 1920 and 35 tons during 1919 in the first 6 months.

CAUSTIC SODA

The production of solid caustic soda was increased during the war from an annual average of 3,200 tons to an average of 14,000 tons, and that of strong caustic soda solutions, or lyes, from 8,000 tons to 28,320 tons. After the war, however, it had to compete against the reductions that followed through the competition of foreign products. During the first half of the past year foreign competition reduced its exportation, which amounted to only 290 tons, against 1,702 tons in 1920 and 45 tons in 1919 during the corresponding period. The importations remained high, being 4,412 tons, against 18,831 tons in 1920 and 3,669 tons in 1919.

GOLD IN THE TICINO RIVER

The Ticino River, a large stream flowing to the River Po in the north of Italy, has sands that contain gold flakes and grains in quantities varying from 0.25 to 6 g. per cubic meter. This metal is always combined with silver (10 per cent), more rarely with palladium, and with it, at a depth of 15 meters, is also found iron, chromium, molybdenum, nickel, thorium and radium. Proper exploitation of this sand has not yet been undertaken, but a campaign has been started to this end.

SUSPENSION OF ELECTRIC ENERGY IN THE NORTH OF ITALY

Through the precautions taken to avoid waste, greater intensity of the generating plants employing coal, benzine, petroleum, heavy mineral oils and weak fuels, an increase in the water power available and the importation of 150,000 kw.-hr. from Switzerland, the quantity of electric energy available has been increased and some of the railways have resumed the use of electric current. For some time they have been compelled to use steam. However, there is still a scarcity of electric energy for industrial plants.

DEVELOPMENTS IN HYDRO-ELECTRIC PLANTS

With the Piave S. Croce hydro-electric plant Italian engineers expect to get 140,000 electric horsepower during 1922. By 1924 it is expected this will be increased to 200,000 and by 1928 to 300,000 and more. This will be sufficient to operate all the electric plants and railways in the Veneto region. The expense of the hydro-electric plant is estimated at about 1,300,000,000 lire.

Sectional Meeting, American Society for Steel Treating

SEVERAL local chapters of the American Society for Steel Treating, from Boston to Washington, met in New York Friday afternoon and evening, March 3, for a sectional meeting of the society. It is planned to hold three of these gatherings at various centers during the year, in addition to the regular annual convention. At least two aims may be accomplished. First, to give members who have not the opportunity to go to some far distant general convention the privilege of meeting men from other localities and discussing everyday problems with them. Second, directors' meetings will be held during the sectional meetings, thus permitting the general executives of the society to appraise local sentiment without an excessive amount of travel.

If the New York meeting may be taken as a criterion, the plan is excellent. About 100 out-of-town members registered, which, with an equal or greater number of men from the metropolitan district, gave an interested attendance at meetings which would have done credit to many an older society. Thanks to the indefatigable work of Captain Walter C. Graham of the program committee, all but one of the papers had been obtained in time for publication in the February *Transactions*. Members were therefore appraised of what was to be said, and the discussion was correspondingly animated.

A pleasant feature of the evening program was the notification of Dr. John A. Mathews, of the Crucible Steel Co., of his election to honorary membership.

Manufacture of Stainless Cutlery

The one paper not readily available in the published *Transactions* was read by R. G. Hall, of R. Wallace & Sons Manufacturing Co., on "The Manufacture of Stainless Steel Cutlery." He recognized that authorities differ on many essential points, but nevertheless desired to record his personal experiences. For cutlery, carbon should range between 0.3 to 0.45, and chromium from 13 to 15 per cent; silicon 0.30 and manganese 0.50. Although the tendency is for higher carbon and chromium steels, higher carbons produce a steel which punishes cutting dies excessively and is therefore costly to use; as carbon goes up, chromium must also increase in order to resist corrosion. Cutting efficiency —determined by cutting wooden chips on a lathe and noting the time before it is necessary to hone the edge —also increases with high alloying, as may be shown by the last steel in the attached table (a steel, by the way, which cannot be manufactured into cutlery by the methods to be given below). Staining liquid used was concentrated acetic, tartaric and hydrochloric acids.

TABLE I—COMPARATIVE TESTS ON STAINLESS CUTLERY

Analysis		Time to Stain	Cutting
Carbon	Chromium	Minutes	Test
0.30	11.93	28	Good
0.26	17.21	35	Fair
0.40	13.60	13	Good
6.31	15.90	75	Good
1.10	23.32	43	Extremely good

One general precaution is to pay great attention to the tools—a die which is the least bit dull will tear the stock ever so slightly; the resulting damage will not be apparent until the blade is nearly finished. Seamy blades are usually ascribed to poor steel, but in most cases are caused by metal torn during fabrication. Second, even with sharp tools it is also necessary to keep the metal well softened, "annealed" as it is called in the shop, although "tempered" would probably fit the operation better, since it involves a slow cooling from a soaking heat at 1,400 deg. F. (below the critical). Thirdly, all heating should be done in reducing atmosphere, and every precaution made to keep the metal free of scale at all times.

Manufacturing operations are somewhat as follows: The "annealed" stock, which is usually bought in round rods, is cut to proper length, drop forged, trimmed, and the blade rolled. Careful temperature regulation between 1,650 and 1,750 deg. F. is essential for the latter, on account of the abrupt change of section at the shank. Scale must not be rolled into the blade, nor should it be permitted to cool rapidly, as on a damp floor. Premature hardening causes internal strains and cracked articles. Next the forged and rolled piece is softened at 1,380 to 1,400 deg. F. in a muffle, slowly cooled, and the blades are blanked out, using *sharp* tools.

Now follows the hardening, which is the most difficult part of the operation, affecting not only the cutting qualities of the knife, but also its resistance to strain. For several "practical" reasons Mr. Hall prefers to quench in oil from 1,650 to 1,950 deg. F., depending upon the composition, although he recognizes that the British practice is to water-quench, and no difference in microstructure is discernible. The hardened blade is then tempered so that when loaded centrally it will bend 1 in. in 5 without a set, and have a Brinell hardness of 525 to 550. Time and temperature are adjusted to the steel for this result. Commonly 15 minutes at 650 deg. F. is correct. Since temper colors appear in heated stainless steel at about twice the heat of carbon steels, and are also unreliable, a bath should be used.

Grinding should be done without haste. Heavy grinding induces staining—the first evidence is "grinders' scorch," which polishes off easily enough but leaves an area which stains again very easily. It is also necessary to grind to the bottom of all pits and surface imperfections, since a minute amount of adhering mill scale will cause delayed staining and many complaints after blades have been in satisfactory service for months. Cutlery is then glazed on a fine wheel to remove grinding marks, inspected, mounted in the required handle (soldered to hollow handles, welded to solid ones), again glazed and tested for stainless qualities by immersion for 2 minutes in concentrated copper sulphate solution. Finally the accepted knife is etched, wrapped and stocked.

Magnetic Testing of Chain

A brief paper on this subject read by A. V. de Forest, research engineer, American Chain Co., proved exceptionally interesting, since the author had brought with him the electrical equipment and sample chains necessary for making the required tests.

Anti-skid chains are exposed to extremely severe service, and it has been found on road test that a certain depth of hardened case gives longest life; shallow cases are too soft, while deep ones are too brittle. Magnetic testing has proved of extreme value in promoting uniformity of product; if road tests indicate that a certain stock, carbonized and heat-treated in a certain way, will give superior wearing qualities, then the magnetic test may be relied upon to hold the mill production as close to this given ideal as desired. Or, if all manufacturing conditions but one are held constant, the magnetic test will very sensitively indicate values of that variable.

Electrical Porcelain Manufacture

Description of the Plant and Operations of R. Thomas & Sons at East Liverpool, Ohio — Production of Ware for High- and Low-Voltage Uses—Raw Glazes Employed—Body Similar to Chemical Stoneware—Ceramic Control

BY CHESTER H. JONES

THE 12-kiln plant of R. Thomas & Sons, manufacturers of electrical porcelains, is well located in East Liverpool, Ohio, for while the ultimate product and markets are different from tableware, the operations in the plant are essentially those belonging to the white ware pottery. The labor market is also best at this point. The plant produces a general line of insulators for low- and high-voltage electrical construction, while the 10-kiln plant at Lisbon, Ohio, is devoted to the manufacture of the patented Hewlitt insulator. The Lisbon plant was originally built to manufacture tableware.

R. Thomas, together with his son, the late George W. Thomas, organized the present company in 1873, building the first plant in East Liverpool. It was the first firm in the United States established for making high-voltage porcelains. Low-voltage porcelains are made by the dry process, where the dried cake from the filter press is ground to powder and compressed in heavy molding machines. High-voltage porcelains follow the method of molding the plastic clay employed in chinaware plants.

Storage and Blunger House

The raw materials used are kaolin or English china clay, English ball clay, flint or ground silica, feldspar, barium carbonate, magnesium carbonate and calcium carbonate. Raw white glazes are made up of these materials, no frits being used. Colored glazes are made from Albany slip, feldspar and flint. The top of the raw storage piles and blunger house is on a level with the incoming railroad tracks. The materials are delivered from cars to storage by an endless belt and tripper to four of the seven concrete bins and direct by shovel to the remaining three.

Fig. 1 is a view in the aisle of the blunger house. On the left are the blungers with feed openings nearly on a level with the Fairbanks transfer table scales appearing in the center. This weighing outfit is so arranged that the scale car can be wheeled into each concrete raw material bin for loading. The doors of two of these bins are seen on the right. A blunger charge for the wet process slip weighs 5,400 lb. and for the dry process 6,500 lb. There are four blungers, consisting of steel tanks lined with vitrified brick and equipped with double agitators. The line shaft driving the blungers through bevel gears is in turn driven by a 20-hp., 220-v., two-phase motor.

FIG. 1—TRANSFER SCALES

FIG. 2—SLIP PUMP AND BLUNGERS

Three blungers operate on the wet-process slip, the remaining one on the dry-process. The charge is blunged 1 hour to give the necessary creamy slip. Three agitated storage cisterns below the floor receive the slip from the blungers. The three blungers deliver into two of these, while the third receives the dry-process slip from one blunger.

Fig. 2 is a view on the delivery side of the blungers, with the wet-process double-acting slip pump in the foreground. This pump delivers wet-process slip from the two cisterns to the lawn room in the main buildings located up hill from the railroad. A similar pump likewise handles the dry-process slip from the third cistern to a second lawn room. These pumps are also equipped with 20-hp. Westinghouse motors.

Sagger Room

The saggers for holding insulators while burning in the kilns are made as usual in a separate department. Raw materials used for making these saggers are Kentucky ball clay, Pennsylvania sandy clay, wad clay and

grog. The equipment here consists of a small dry pan, grinder, vertical pug mill, small wad mill and a 28-ton steam press having a pressure of 250 lb. per sq.in. for forming the sagger. The wad mill is a small affair extruding a plastic clay string about ¾ in. diameter. This is used between the top edge and the lid of the complete sagger for sealing in the ware, thus preventing the entrance of kiln gases and resultant contamination of the ware.

The formed sagger from the steam press is dried thoroughly by placing over a gas flue. It is not necessary to burn the saggers in separate kilns, as often

FIG. 3—LAWN ROOM PUMP

practiced. The "green" product from the drying flue may be filled and burned at the same time as the ware it contains.

Lawn Rooms

The slip for dry body or low-voltage porcelain is delivered from the blunger house as mentioned above to a cistern in the low-voltage lawn room. Thence it is pumped onto a 120-mesh lawn shaker screen and returns to a second cistern, where it is agitated until delivered by a second pump at 80 lb. pressure to the filter room.

The larger or high-voltage lawn room is equipped with two units, each consisting of a cistern receiving slip from the blunger house, a 120-mesh shaker lawn,

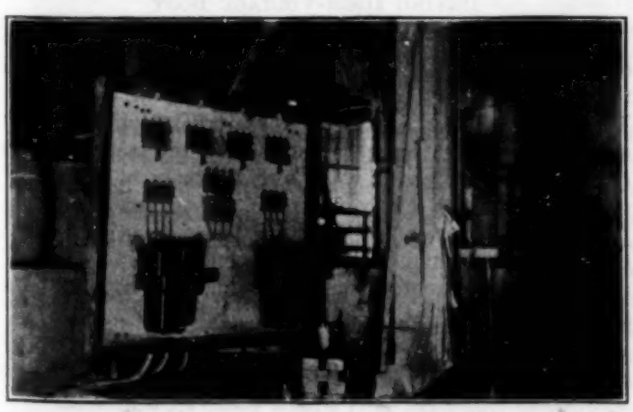

FIG. 4—LAWN ROOM SWITCHBOARD

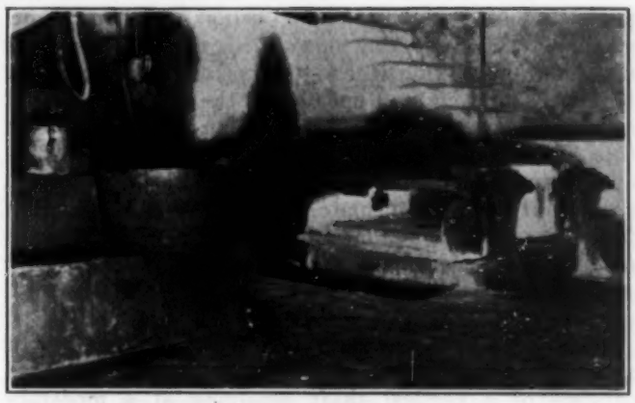

FIG. 5—SHAKER LAWN

a second cistern and a pump delivering the finished slip to the filters. Fig. 3 shows one of the double-acting pumps in the high-voltage lawn room driven by two-phase electric motor, and Fig. 4 shows the switchboard, carrying oil switches, fuses and knife switches controlling the pump motor circuits and shaker lawn motor. The shaker lawn appears in Fig. 5.

The glazes made from white ingredients or Albany slip without frits are ground in three 1,000-lb. pebble mills adjoining the high-voltage lawn room. Fig. 6 shows a portion of one of these arranged with belt drive.

Filter Room

Production of the plastic cake from the slips as they are pumped in from the lawn rooms is carried on in one location with a battery of seven 80-lb., leaf type, Patterson filter presses. One press is used on low-voltage and six on high-voltage body. For dry-process low-voltage porcelains, the cakes from the filter press

FIG. 6—PEBBLE MILL FOR RAW GLAZES

are elevated to a drying room located over the kilns and after thorough drying are pulverized and tempered for pressing to shape.

For wet-process, high-voltage porcelain the plastic cakes are piled in a heap, beaten with mallets into a solid mass and permitted to age for a period varying from 1 to 3 days. During this time the moisture becomes evenly distributed throughout the mass. Just before it is sent on to the shaping department it passes a vertical type pug mill. This operation consolidates the clay, works out any air bubbles and forms it to suitable slabs for working.

Pugging

The pug mill consists of a vertical hollow cylinder, in the middle of which revolves a shaft carrying

projecting blades. The blades, being set at an angle, gradually force the clay downward, at the same time kneading and mixing it. At the bottom of the cylinder it is forced through an opening in the side, coming out as a continuous bar from 4 to 6 in. in diameter. From this bar slabs are cut of suitable length for subsequent processes. Pugging is an important operation in the manufacture of insulators, for upon it depends the freedom of an insulator from checks and air bubbles and the consequent ratio of dielectric strength.

Shaping High-Voltage Insulators

The jigger room is equipped with about ten jiggers and several hot presses. The jigger as here employed consists of a vertical shaft revolving at a moderate speed and having at the top on a level with the workman's bench a plaster of paris mold to form the outside shape of the piece. A lump of pugged clay is dropped into the mold and formed roughly to shape by hand. The metal template, called a tool or shoe, having the contour of the inside surface of the insulator, is then pressed down by means of an arm attached to the machine and the finished interior outline given. The mold containing the shaped piece is then removed and another mold dropped into place for the next piece.

The pieces are permitted to remain on shelves in molds for 24 hours. The mold is then opened up, the piece removed and set upon boards or cars in readiness to be taken to the drier.

Hot Pressing

The hot press room contains eight hot presses, a machine similar in general characteristics to the jigger. Fig. 7 shows one of these ready for the operation.

FIG. 7—HOT PRESS

Different from the jigger, the table below does not revolve, but holds the plaster of paris mold solidly in position. A circular billet of clay with one end rounded is thrown with round end down into the mold.

While the machine is in the position shown two gas flames play upon the upper cast-iron half of the mold, keeping it warm between movements. These gas burners are visible between the upper and lower halves of the mold. It will be noted that the upper half is threaded and grooved to form the inside of the insulator. The crosspiece above acts as a guide for the threaded mold shaft.

After the clay is placed in the lower half, the operator throws on power, causing the shaft to revolve, and due to threads on shaft of the same pitch as the threads on the mold the upper half moves downward quickly and enters the clay, forcing it to fill all the space between the upper and lower halves and simultaneously forming a thread on the interior of the piece. At the end of the travel the piece is thus shaped, the power is reversed and the upper half unscrews upward to its original position, to be heated again by the gas flumes.

The heating of this mold causes a film of steam to form when it comes in contact with the wet clay, giving a clean-cut surface and, still more important, permitting an immediate removal of the iron from the clay without danger of sticking. The iron mold is hollow, avoiding suction by permitting air to pass through small holes when it is withdrawn. The operation may be repeated very rapidly, the speed being entirely dependent on how quickly the lower half may be removed from the machine and a new plaster of paris mold inserted.

As in the case of jigger work, the piece is permitted to remain in the mold 24 hours before removing and transporting to the drier.

Other Shapes

The method of shaping the high-voltage pieces depends upon the article to be made. Pieces of a diameter rather large in proportion to the height, such as pin and suspension insulators, are made on the jigger or press as above described. Long corrugated pieces like bushings and post insulators are turned. This turning may be done on a special lathe or jigger. It is essentially the same as wood turning. Wet turning is most advantageous where possible because of increased speed and lack of dust.

Plain tubes are made by extrusion from a machine composed essentially of a cylinder and a piston. In the bottom of the cylinder is placed a die having a hole equal to the outside diameter of the desired tube and a concentric mandrel to form the bore. In the case of small tubes several may be extruded simultaneously. The cylinder is filled with pugged clay, the piston moves slowly down, squeezing the clay from the die in the form of a continuous tube. Suitable lengths are cut off and straightened by rolling. The head is pressed up on small tubes and spun on in the larger sizes.

Drying High-Voltage Body

All of the various pieces having been placed on rack cars after removing from the molds, these are wheeled to the entrance of the large drier as shown in Fig. 8. This drier is 104 ft. long and three tracks wide. It has a capacity of nineteen cars per track. One track handles cars containing larger ware and operates at a rate of one car entering every 3 hours, or giving a drying time on each car of 57 hours. The two other tracks carry cars of smaller ware and operate on a 2-hour schedule, consequently giving a drying time of 38 hours per car.

Proper regulation of drying rate is one of the most important features of insulator manufacture. Extreme care must be taken or cracks and warping will develop, affecting both the mechanical strength and dielectric

FIG. 8—RACK CARS ENTERING DRIER

properties of an insulator. Before the advent of the mechanically operated, automatically controlled drier in the ceramic industries it was necessary to place the ware in a heated room with little humidity control for a period of from 2 to 6 weeks.

The insulation at this plant is a Hurricane drier manufactured and installed by the Philadelphia Drying Machinery Co. The humidity and air supply is automatically controlled by wet and dry bulb Tycos regulators. Fig. 9 is a part view along the drier showing blower drive and control.

There are nine fans alongside the drier, all driven by a 25-hp. two-phase motor. Steam at 100 lb. pressure is supplied to the coils. All steam used in the plant is purchased from an adjoining factory. An air pump furnishes 25 lb. air pressure to operate the diaphragm valve on the controls. There are four sets of control mechanism for automatically handling the supply of steam and air to the drier. Pieces from the drier are conveyed to the glaze dipping room.

Dry-Process, Low-Voltage Room

Low-voltage body in the form of filter cake, having been passed through the drier on cars along with the high-voltage shapes and subsequently stored in a heated room over the kilns, is sent to the low-voltage shaping room. Here it is rough ground to nut size and mixed with just sufficient water to make a damp powder without becoming plastic. It finally passes through a plate type grinder running at 2,200 r.p.m., coming out as a fine damp powder. Two complete grinding units perform this operation.

Arriving in the press room through a chute from above, the powder is shaped in about fifty different hand presses to the forms required. The dies used in these presses are lubricated with a special oil known as Franklin XX. After trimming off the rough edges by hand, an operation known as fettling, the pieces are transported on trays to the dipping room.

Dipping Room

Both high- and low-voltage bodies are dipped by hand in tubs of wet raw glaze. The ingredients of the glaze are ground with water as previously noted. Colors are often introduced in glazes to identify electrical circuits when the insulators are in place. These include chromium, cobalt, Albany slip, a dark brown and the natural white. Before dipping in the glaze the pieces are immersed in water to remove dust which may have accumulated through the process. The dipped pieces are allowed to drain and dry in the air and are then ready for the kiln. In cases where it is desirable to roughen part of the surface of the insulator to give friction where in contact with insulator pin or for other reasons, the part is coated with paraffine, then with a mixture of sodium silicate and gum arabic and dipped in high-voltage sand. The sand adheres to the sticky surface, giving the desired roughness. The portions of all insulators which come in contact with the sagger are paraffined.

Firing

The kiln room is equipped with twelve updraft periodic kilns of 12, 14 and 16 ft. diameters. Materials and saggers are handled in and out of the kilns by Lowden overhead conveyors. When the saggers of ware are stacked in the kilns, the green or unburned saggers are placed near the top above the jack saggers.

Actual firing time varies from 40 hours on the small ware to 70 hours on the larger pieces. During the first stage the temperature is raised and the moisture is driven off. This moisture includes that merely mixed with the clay which has not been driven off in drying and also that which is chemically combined with the clay particles as an essential constituent. The latter action is accomplished at about 1,200 deg. F. and is a true decomposition of the clay substance. In the next stage the temperature is raised to proper value for the vitrification to porcelain and is held there until a heat-saturation point is reached as indicated by cone 11.

FIG. 9—VIEW ALONG DRIER SHOWING BLOWER DRIVE

This is a delicate stage. If the temperature is too low, the porcelain is underfired and porous, and if too high, it becomes brittle, full of bubbles and therefore electrically weak. During the last stage the kiln is allowed to cool gradually so that the ware is well annealed. The entire cycle requires about 5 days.

Fuel

Three of the kilns burn coal, three gas with natural draft burner and the remaining six burn fuel oil or gas. The combination burners on two of the kilns are the Maxon Premix and on four kilns are Spencer burners made by the Leader Furnace Equipment Co., Cleveland, Ohio. Fig. 10 shows the new type gas-oil burner applied through the ash door of a kiln. The oil is sprayed into the space below the firebox at a pressure of 30 to 40 lb. with air pressure at a maximum of 3 oz. The oil nozzle is cut with cross-shaped slot. Fuel oil is purchased from the Oklahoma fields and is a refining residue. The main storage tank holds 200,000 gal., with an auxiliary tank of 6,600-gal. capacity.

Fig. 11 is a view of the natural draft burner adapted through ashdoor.

FIG. 10—NEW TYPE GAS-FUEL OIL BURNER

FIG. 11—NATURAL DRAFT GAS BURNER

An average kiln consumes about 2,000 gal. of fuel oil per burn, making a fuel cost of $70. To do the same work 220,000 cu.ft. of gas is required at a cost of $100. Twelve tons of coal at $5 per ton is used per burn, at a cost of $60 plus the cost of cleaning and ash-handling. It is obvious that oil is the most economical fuel for this plant.

Assembling

After the burning operation the insulators are sent to the assembling and testing departments. The parts of pin and suspension insulators are fastened together with portland cement mixed neat and just thin enough to flow readily. The tubes of roof and wall bushings, not being exposed to much mechanical strain, are fastened together with an asphalt compound which incidentally gives increased insulation.

Electrical Testing

Dry-process porcelain, being for low voltage, is not ordinarily subjected to electrical tests. On the contrary, the wet-process, high-voltage product must undergo not only electrical but also mechanical tests. Electrical tests which do not injure the test-piece, to determine size and proportion such as measurements of dry and wet flashover, corona voltage, etc., are usually made on a few samples. Electrical tests are made where the proportions and size are assumed to be correct and it is required to determine the limitations of the porcelain or compare with some standard.

Where the ultimate limit is to be determined, the piece is destroyed, which prevents the application of the test to more than a small fraction of the product. The puncture under oil test and the ultimate mechanical strength test are examples. The particular sample being destroyed, the only value of such tests lies in what may be inferred as to the qualities of the large proportion not tested.

Where the material is merely required to come up to a certain standard, only pieces failing to meet it are destroyed. Common examples are the routine flashover test in the pan applied to all insulators, and with suspension insulators the test load. Good judgment is required in laying out such tests. They should be severe enough to remove really defective material but not injure or weaken average or good material. This is complicated, since there is no sharp distinction between good and bad, and all intermediate grades will exist. For commercial purposes the test must be such that most of the material if of average quality will pass it, and the pieces so selected will stand the working conditions. If these features are not consistent, a design of stronger proportions must be selected.

Dimensions of Porcelain Pieces

The accuracy to dimensions of porcelain is affected by a number of factors. There is first the wear of the molds. This is important with both steel and plaster molds. The greater the variations which can be permitted the longer the life of the mold. Next comes the shrinkage in drying. This depends upon the amount of moisture in the clay, and is difficult to control very closely. Finally there is the shrinkage in firing. Of course exactness in dimensions can be obtained by gaging and rejecting all parts outside the limits, but this is scarcely possible except in the few instances in which the rejected pieces can be used for other purposes where exact dimensions are not so important. In some cases the variation can be reduced by special attention to the moisture content, by trimming after drying, or grinding to size after firing. All such methods cause added expense, and unless really necessary are avoided. Good commercial limits which do not involve any unusual precautions are a total variation from minimum to maximum of $\frac{1}{32}$ in. per inch for dry process porcelain, and $\frac{1}{16}$ in. per inch for wet process.

Shipping Room

The inspected and tested insulators finally arrive at the shipping room, where they are packed with shavings in barrels and crates. The finished package is weighed over an American Kron scale and passed into the cars.

Ceramic Laboratory

In addition to research work the ceramic laboratory controls the various operations in the plant. Moisture factors must be taken on all raw materials. Porosity and screen tests are made on clays. Chemical analysis is made on feldspar and elutriation tests on flint and feldspar. Some test must be made of the lime content of the flint.

Ball clay vitrifies at cone 11 but does not overfire, because of long vitrification range. It also has high mechanical strength. Electrical porcelain is a vitrified ware, where tableware made in this district is only semi-vitreous. Naturally the body used is difficult to dry because of high ball clay content. China clay runs more uniform and causes less trouble.

The body mixed is controlled by regular tests which effect the length of time to age, the moisture in the filter cake and the operation of the drier. The uniformity of mixture secured by aging is most important in the manufacture of porcelain. It resembles chemical stoneware in this respect.

Concentrating Dilute Nitric Acid Solutions

Results of Experimental Studies on the Concentration of Dilute Nitric Acid by Distilling at Atmospheric Pressure While Keeping the Liquid and Gas Phases in Equilibrium

By CLIFFORD D. CARPENTER and JOSEPH BABOR
Department of Chemistry, Columbia University

ZEISBERG has recently translated for this journal two articles on the concentration of nitric acid. In the first[1] Galle has considered the preconcentration of dilute acid by fractionation and its superconcentration in the presence of sulphuric acid. In the second[2] Pascal has studied the binary system nitric acid-water (Part I) and the ternary system water-nitric acid-sulphuric acid (Part II).

As a result of his experiments Galle advises preconcentration to about 65 per cent acid solution. The results given in his Table III show that he fractionated 33.8 per cent nitric acid to a strength of 65 per cent with a negligible loss either as nitric acid or by decomposition. A thermometer sealed in at the top of his fractionating column remained at 98 to 99 deg. C. throughout the experiments. When he made an attempt to concentrate farther the temperature rapidly rose and nitric acid came over in the vapor. During the last 2 years students[3] have concentrated dilute nitric acid solutions by fractionation in an apparatus identical to the one described by Galle except that the fractionating column was not as thoroughly lagged and the heating of the flask was accomplished by a bath of calcium chloride solution. It was found by them that when heated directly by the flame considerable more decomposition of the acid took place. In general it was found that the acid could be brought to about 35 per cent with very little loss of acid, but that the amount of acid in the distillate increased very rapidly as the concentration of the residue increased above this point. It would seem that Galle had an exceptionally efficient fractionating column.

TABLE I—CONCENTRATION OF NITRIC ACID BETWEEN 6.533 AND 59.72 PER CENT

Weight of Residue, g.	Weight of Total Distillate, g.	HNO_3 in Distillate, Per Cent	Total Distillate, Per Cent	HNO_3 in Residue, Per Cent	Temperature of Bath, Deg. C.
618.370	.....	.....	.....	6.533	.....
559.33	59.04	0.07	9.55	7.21	110–112
495.20	123.17	0.17	19.92	8.12	110–112
451.20	167.17	0.25	27.04	8.90	110.112
403.68	214.69	0.35	34.72	9.92	112
339.67	278.70	0.54	45.07	11.74	112
277.41	340.96	0.84	55.14	14.26	113
218.93	399.44	1.33	64.60	17.85	113
161.99	456.38	2.30	73.81	23.52	114
111.48	506.89	4.59	81.97	32.13	114
79.15	539.22	8.46	87.20	40.36	117
51.69	566.68	15.42	91.80	48.33	119
32.29	586.08	22.34	94.78	55.95	120
24.97	593.40	25.49	95.96	59.72	122

Pascal has studied the nature of the vapor phase in equilibrium with the liquid phase at various pressures and temperatures and finds considerable decomposition at the higher temperatures.

In connection with a study of several ternary systems which the authors are making at the present time, the binary system water-nitric acid has been briefly studied. Like Pascal, we have kept the vapor in equilibrium with the liquid phase throughout the distillation, but have considered the results in a slightly different manner. A description of our apparatus,[4] method of procedure and a discussion of our results are given below.

Apparatus

A complete diagram of the apparatus is shown in Fig. 1. The distilling flask and delivery tube is completely immersed in a bath (a solution of calcium chloride) so that the vapor will not condense until it enters the condenser. The condensed liquid then drains down directly into the receiving vessel. A glass stopcock is sealed onto the delivery tube so that there will be no loss of distillate which runs down while the flask which has received the first fraction is being replaced by a second. The detail of the apparatus is fully given in the figure. The flask and all material coming in contact with the vapor or liquids are of Pyrex.

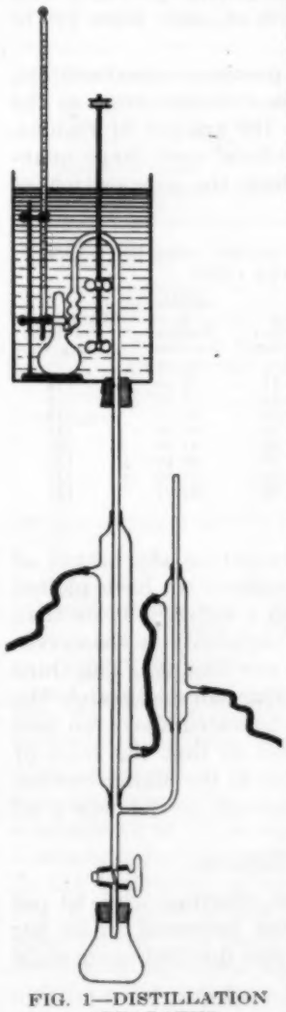

FIG. 1—DISTILLATION APPARATUS

Procedure

A quantity of nitric acid of known concentration is weighed into the flask. The flask is then introduced into the empty pot, the delivery tube led through the stopper in the bottom and then sealed to the inner condenser tube. The bath liquid is then poured into the pot until the flask and delivery tube are well covered. The bath is vigorously stirred and sufficient heat is applied to keep up a slow but continuous distillation. A fraction of 25 or 30 g. is received into a small weighed flask and removed. While a second fraction is being collected the first is weighed and titrated. In this manner a continuous experiment gives a number of values which can be expressed in such a manner that the rate

[1] Elements of the Superconcentration of Nitric Acid, CHEM. & MET. ENG., vol. 25, p. 741, Oct. 19, 1921; translated from *Z. angew. Chem.*, 1921, vol. 34, pp. 168-170, 173-175.

[2] Distillation Studies of Nitric Acid and Sulphuric-Nitric Acid Mixtures—I, CHEM. & MET. ENG., vol. 25, p. 1103, Nov. 14, 1921; II, CHEM. & MET. ENG., vol. 25, p. 1145, Nov. 21, 1921; translated from *Ann. Chim.*, 1921, new series, vol. 15, pp. 253-290.

[3] Chem. 104. Advanced Inorganic Preparations.

[4] Although the apparatus and method is very similar to that of Pascal, it was designed and used 2 years ago, when this work was first started.

of concentration of the acid is known. All experiments were carried on at atmospheric pressure. The results of three experiments are given in Tables I, II and III respectively and these results are graphically expressed in Fig. 2.

In the first experiment 618.37 g. of 6.533 per cent nitric acid was concentrated to 59.72 per cent acid while the temperature of the bath changed from 110 to 122 deg. C.

TABLE II—CONCENTRATION OF NITRIC ACID BETWEEN 6.533 AND 53.25 PER CENT

Weight of Residue, g.	Weight of Total Distillate, g.	HNO_3 in Distillate, Per Cent	Total Distillate, Per Cent	HNO_3 in Residue, Per Cent	Temperature of Bath, Deg. C.
705.995	.....	.....	.....	6.533	.....
638.73	67.27	0.09	9.53	7.21	110-114
570.79	135.21	0.17	19.15	8.05	114
501.16	204.84	0.30	29.01	9.14	115
437.19	268.81	0.47	38.08	10.44	116
366.63	339.36	0.73	48.07	12.38	117
309.18	396.82	1.05	56.21	14.58	118
256.15	449.85	1.49	63.72	17.42	119
211.67	494.33	2.11	70.02	20.79	120
172.93	533.07	3.06	75.50	24.90	120
132.50	573.49	5.03	81.23	31.01	121
109.95	596.05	7.11	84.43	35.48	122
85.43	620.56	10.86	87.90	41.27	123
56.15	649.85	18.79	92.05	48.67	124
34.71	671.28	27.64	95.08	53.25	124

In the second experiment 705.995 g. of 6.533 per cent nitric acid was concentrated to 53.25 per cent acid while the temperature of the bath changed from 110 to 124 deg. C.

In the third experiment 517.56 g. 38.518 per cent nitric acid was concentrated to 51.915 per cent acid while the temperature of the bath changed from 118 to 122 deg. C.

As has been pointed out by previous experimenters, the results become more or less unsatisfactory as the amount of distillate approaches the amount of residue. In studying the salt effect. McBain[1] used large quantities of dilute solutions and took the composition of only one small fraction as representing the nature of the vapor phase. In Fig. 2, however, we have plotted the results of our experiments on a different basis than previous experimenters and the regularity of the curves indicates the probable value of our results. The third experiment is given in order to give more accurately the upper portion of the curve. As is stated above, an acid of higher concentration was used so that the ratio of the amount of distillate to residue in the higher concentrations should not be large enough to introduce an error.

TABLE III—CONCENTRATION OF NITRIC ACID BETWEEN 38.518 AND 51.915 PER CENT

Weight of Residue, g.	Weight of Total Distillate, g.	HNO_3 in Distillate, Per Cent	Total Distillate, Per Cent	HNO_3 in Residue, Per Cent	Temperature of Bath, Deg. C.
517.5621	.....	.....	.....	38.518	.....
493.17	24.39	3.94	4.71	39.63	118
463.04	54.53	9.37	10.54	41.03	118
418.22	99.35	18.76	19.20	43.19	119
366.54	151.02	31.84	29.18	45.70	119
321.10	196.46	45.58	37.96	47.89	119
282.84	234.72	58.90	45.35	49.66	120
245.19	272.37	73.59	52.63	51.30	121
230.65	286.91	79.61	55.44	51.92	122

Discussion of Results

A study of Fig. 2 shows that starting with 10 per cent nitric acid, its concentration increased to 20 per cent when little more than half had distilled over, while from 10 to 40 per cent about three-fourths distilled over. Thus as the concentration becomes higher the rate of concentration becomes less. The data from experiment 3, Table III, lie on almost a straight line between 40 and 50 per cent. When the line is extrapolated it passes through the point of constant boiling acid as the last fraction comes over. It would appear therefore from Fig. 2 that an acid of constant boiling point could not be prepared by simple distillation. This is in accordance with what might be expected, as the concentration of the acid in the vapor is continuously below, although continuously approaching, that of the acid in the residue; the point at which this change becomes zero, of course, is at the point at which all the solution distills over.

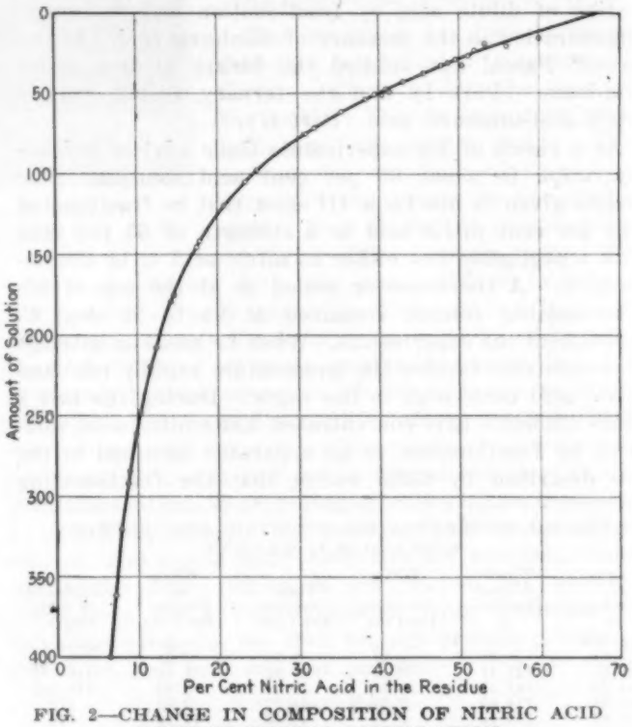

FIG. 2—CHANGE IN COMPOSITION OF NITRIC ACID RESIDUE DURING DISTILLATION

A study of Fig. 2 shows that in a distillation of 1,000 g. of a 10 per cent solution, the concentration would change as in Table IV.

TABLE IV—INTERPRETATION OF FIG. 2

Total Solution, g.	Water, g.	Acid, g.	Concentration of Residue, Per Cent HNO_3	Loss of Acid, Per Cent of Total
1000	900	100	10	0
484	387	97	20	3
302.3	212	90.7	30	9.3
197.7	118.6	79.1	40	20.9
108.6	54.3	54.3	50	45.7

Summary

1. Experimental data are given to show how nitric acid concentrates when it is distilled at atmospheric pressure, with the vapor phase in equilibrium with the liquid phase.

2. It is evident that concentration of dilute nitric acid could not be profitably carried on above 20 to 30 per cent by such a distillation, as 3 per cent is lost as the concentration changes from 10 to 20 per cent and 9.3 per cent as the concentration changes from 10 to 30 per cent.

New York City.

[1] *J. Chem. Soc.*, vol. 115, pp. 1332-46 (1919).

Relation of Shale-Oil Residue to Other Bitumens*

A Preliminary Study of the Resemblance of Some of the Physical and Chemical Properties of Heavy Shale-Oil Materials to Those of Gilsonite, Asphalt and Rosin

By C. W. BOTKIN
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SOME of the properties of the heavy residues from representative Colorado and Utah shale oils were given in a former article.[1] These properties suggest resemblance to better known and widely used bitumens and it is therefore desirable to study the relation of this "shale-oil residue" to other bituminous materials. In the study presented in this paper special attention has been given to the products of thermal decomposition at atmospheric pressure and to the effects of the decomposition on saturation and nitrogen content. Wherever data on the different bitumens could be found in the literature they have been freely used. However, little information could be obtained on the saturation of the oils produced by destructive distillation of the other bituminous materials, and it was necessary to make a distillation of each substance studied. These distillations have been made for gilsonite, asphalt and rosin, but experimental work planned for grahamite and petroleum residues has been postponed because of difficulty in obtaining authentic samples.

The destructive distillations were made in the same way as the distillation of the "shale-oil residue."[2] The oils obtained were tested for gravity and saturation,[3] then fractionated and the boiling point, gravity and saturation of each fraction determined. The distillation of the bitumen and of the resulting oil was in each case made from Pyrex distilling flasks at atmospheric pressure without steam. The gilsonite and gilsonite oil were also analyzed for nitrogen and sulphur. The data for gilsonite and the gilsonite oil are given in Table I, for asphalt and the asphalt oil in Table II, and for rosin and the rosin oil in Table III. Fig. 1 shows the saturation curves for the oils from the "shale-oil residue," gilsonite, asphalt and rosin and for the once-run Nevada oil[4] and the once-run Utah oil No. 2.[5] Fig. 2 gives specific gravity-boiling point curves for these oils, for the once-run Utah No. 1 and for pure paraffines, and indicates the position relative to the curves of the boiling point and specific gravity of a number of olefines and cyclic hydrocarbons. Table IV is a tabulation of some of the properties of the "shale-oil residue" and the corresponding properties of gilsonite, grahamite, asphalts and petroleum residues. The values for the asphalts and petroleum residues are based largely on data given by Richardson in his "Modern Asphalt Pavement, 1910," and the values for gilsonite and grahamite on the work of William C. Day, Mabery and Richardson. Credit in most instances is given in the footnotes to the table. The data (Table IV) on the "shale-oil residue" and on the products and effects of destructive distillation are taken from a former paper.[1]

The data of Tables I, II and III show a number of interesting phenomena relative to each substance that are not directly pertinent to the objects of this investigation and will not be further mentioned. A study of the data tabulated in Table IV and of the curves in Figs. 1 and 2 will serve to indicate the chief relations of the "shale-oil residue" to the other bituminous materials.

Resemblance of Shale-Oil Residue to Gilsonite

The "shale-oil residue" more nearly resembles gilsonite than any other bitumen. These materials are very much the same in gravity, high content of unsaturates and malthenes and low content of carbenes; in percentages of nitrogen, sulphur and fixed carbon; in yields of coke, gas and "additional saturates" on destructive distillation, and in the properties of the oils obtained by decomposition. The oil from the "shale-oil residue" has a saturation of 54 per cent and the oil from the gilsonite a saturation of 55 per cent. Fig. 1 shows a similarity in the saturation of the fractions of these oils, and Fig. 2 indicates almost identical specific gravity-boiling point curves. The main points of difference are a higher content of malthenes and a higher percentage of high melting point paraffines in the "shale-oil residue." This difference in heavy paraffines is indicated by the amount

TABLE I—DATA ON DESTRUCTIVE DISTILLATION OF GILSONITE

500 g. distilled from a 1,000-c.c. Pyrex distilling flask

Water, per cent by weight	1.0
Oil, per cent by weight	54.5
Coke, per cent by weight	27.8
Gas, by difference	16.7

Changes Produced by Distillation of Gilsonite

	Gravity	Saturation Per Cent	Nitrogen Per Cent
Before distillation	1.038	6.6	2.32
After distillation	0.8679	55.0	1.02

Additional saturates, per cent*	29.0
Loss as gas and coke, per cent	44.5
Loss of nitrogen, per cent	76.3

Results of Fractionation of Oil From Gilsonite
250 c.c. distilled from 500-c.c. Pyrex distilling flask

Percentage-off	Vapor Temperature, Deg. F.	Gravity (Of 10 Per Cent Fractions)	Saturation Per Cent
10	290	0.719	70.0
20	375	0.783	69.0
30	445	0.816	68.2
40	492.5	0.842	66.0
50	532	0.861	63.0
60	580	0.882	60.0
70	624	0.899	56.5
80	667	0.910	53.2
90	695	0.924	48.8
96.4	705 650	0.953	43.0
Composite of above		0.855	60.4

Products of Distillation of Gilsonite Oil

Oil, per cent by weight	95.0
Coke, per cent by weight	3.2
Gas, by difference	1.8

*For explanation of "additional saturates" see CHEM. & MET. ENG., vol. 26, No. 9, pp. 399, March 1, 1922.

*Contribution from the Research Laboratories of the Colorado School of Mines.

[1] CHEM. & MET. ENG., vol. 26, No. 9, p. 398, March 1, 1922.

[2] CHEM. & MET. ENG., vol. 26, No. 9, p. 400, March 1, 1922.

[3] For method see CHEM. & MET. ENG., vol. 24, p. 876, May 18, 1921.

[4] Distillation data, CHEM. & MET. ENG., vol. 24, p. 879.

[5] Distillation data will be given in a subsequent paper.

of wax which crystallized from the heavy fractions of the oil from the "shale-oil residue" and from the position of the specific gravity-boiling point curves for the heavy fractions of these oils. Mabery has shown[6] that a considerable portion of the saturates from gilsonite oil belongs to cyclic series (C_nH_{2n} and C_nH_{2n-2}) and that some of the unsaturates are olefines. The saturation and specific gravity-boiling point curves for the oils from the "shale-oil residue" and the gilsonite indicate that these oils may be composed of similar series of saturated and unsaturated compounds, the proportions of which vary in about the same way throughout the ten fractions. This close resemblance in the properties of the oils obtained by destructive distillation is additional evidence of similarity in the composition of the parent substances. From a chemical standpoint the gilsonite is such bitumen as might have been removed from some oil shales by pressure and a temperature sufficiently high to cause primary decomposition.[7]

Destructive Distillation of Asphalt

The bitumen of the asphalt examined contained 18.1 per cent of saturates and the asphalt oil contained 5.8 per cent of "additional saturates" not present in this bitumen.[8] The asphalt oil decomposes very little on distillation and the content of saturates is not increased. The percentage of saturates in the asphalt oil is lower than in the once-run shale oils, but the distribution is similar. In the light fractions the curves (Figs. 1 and 2) show a rather high content of saturates and considerable likeness in gravity, boiling point and saturation to shale oils, but in the heavy fractions as the gravity increases a difference becomes more and more evident. The gravity and boiling point of the heavier fractions do not indicate the presence of paraffines. The asphalts (Table IV) resemble the "shale-oil residue" in percentage of malthenes, but the malthenes of the asphalts are higher in saturates and sulphur and as a rule lower in nitrogen.

TABLE II—DATA ON DESTRUCTIVE DISTILLATION OF ASPHALT

400 g. distilled from a 1,000-c.c. Pyrex distilling flask

Oil, per cent by weight of bitumen distilled	53.3
Fixed carbon	33.3
Gas, by difference	13.4

Changes Produced by Distillation of Asphalt

	Gravity	Saturation Per Cent
Before distillation	1.154	18.8
After distillation	0.9121	45.0

	Per Cent
Loss as gas and coke	46.7
Additional saturates	5.8

Results of Fractionation of Oil From Asphalt

100 c.c. distilled from 200-c.c. Pyrex distilling flask

Percentage-off	Vapor Temperature, Deg. F.	Gravity (Of 20 Per Cent Fractions)	Saturation Per Cent
10	317	....	....
20	410	0.778	59.0
30	485	....	....
40	537	0.881	53.8
50	575	....	....
60	627	0.926	42.0
70	670	....	....
80	697	0.950	37.4
90	730	....	....
99.3	815	0.976	28.2
Composite of above		0.902	44.2

Products of Distillation of Asphalt Oil

Oil, per cent by weight	97.2
Coke, per cent by weight	1.84
Gas, by difference	0.96

TABLE III—DATA ON DESTRUCTIVE DISTILLATION OF ROSIN

500 g. distilled from a 1,000-c.c. Pyrex distilling flask

Water, per cent by weight	5.0
Oil, per cent by weight	86.8
Coke, per cent by weight	3.7
Gas, by difference	4.5

Changes Produced by Distillation of Rosin

	Gravity	Saturation
Before distillation	1.068	0.2
After distillation	0.9815	20.0

Loss as gas, coke and water	13.2
Additional saturates	17.5

Results of Fractionation of Oil From Rosin

300 c.c. distilled from a 500-c.c. Pyrex distilling flask

Percentage-off	Vapor Temperature, Deg. F.	Gravity (Of 10 Per Cent Fractions)	Saturation Per Cent
10	380	0.875	21.8
20	575	0.957	22.1
30	605	0.967	31.7
40	614	0.975	33.5
50	620	0.978	35.2
60	624	0.979	39.8
70	630	0.980	42.0
80	648	0.986	49.0
90	695	1.000	46.6
99.1	690	1.012	23.0
Composite of above		0.976	22.6

Products of Distillation of Rosin Oil

Oil, per cent by weight	98.6
Coke, per cent by weight	0.8
Gas, by difference	0.6

Peckham[9] has suggested that some of the heavy materials of California petroleum high in nitrogen consist of basic oils combined with feebly acid tars. William C. Day[10] has pointed out resemblance between these petroleums and gilsonite and has made a product called artificial gilsonite by combining, in the vapor phase, the distillation products of fish (basic oil) and pine chips (acidic plant materials). The high nitrogen content of the "shale-oil residue" and the gilsonite suggests that they may be composed of basic nitrogen constituents in unstable combination with acidic resinous materials, and that such compounds may be the source of the saturates formed on decomposition. A destructive distillation of rosin was made to determine whether this material decomposes with the formation of saturated compounds. The rosin contained (data Table III) only 0.2 per cent of saturates soluble in petroleum ether, but the rosin oil, although it was highly unsaturated (20 per cent saturates), contained 17.5 per cent of "additional saturates" not present in the rosin. The oil on distillation showed little evidence of decomposition other than the formation of water. The first eight of the 10 per cent fractions of this oil have an opposite distribution of saturates to that in the shale oils. The rosin oil exhibits the paradoxical behavior of averaging 34.5 per cent for the saturates in the ten fractions, while the composited oil of these fractions tested only 22.6 per cent of saturates. After standing for 3 months, 7.7 per cent of water had separated from the composite of these fractions. The oil then tested 31.2 per cent of saturates. On redistillation the boiling points, except for the first fraction, were practically identical with the former ones and the distribution of the saturates through the fractions was also similar, but each fraction was about 4 per cent higher in saturation than in the first distillation. The composite of the fractions from the second distillation contained 31.4 per cent of saturates when tested in the usual way, while an average of the percentages found in the individual fractions was 38.5 per cent. Strange variations of this kind have been noticed for some shale oils, but the difference between the average and that of

[6] *J. Am. Chem. Soc.*, vol. 39, pp. 2022 and 2023.

[7] Prof. R. D. George has noted minute specks closely resembling gilsonite in Colorado shales. Colorado Geological Survey, Bull. 25, p. 22.

[8] These percentages are based on the weight of the pure bitumen in the crude asphalt.

[9] *Am. J. Sci.*, III, vol. 48, p. 250.

[10] J. Frank. Inst., vol. 145, p. 476.

the analysis of the composite has not usually exceeded 1 per cent and was attributed to experimental error. Error cannot be the cause of this discrepancy in the rosin oil, but the apparent inconsistency may be connected with the water, which was a decomposition product in both distillations. Mills[11] gives bromine numbers for twenty-three fractions of rosin oil obtained by steam distillation. His results indicate a similar distribution of saturates to that of Table III, and the average bromine number for the fractions is about 26 per cent less than for the crude rosin. These data obtained by bromine absorption methods tend to substantiate the data of Table III obtained by absorption in sulphuric acid.

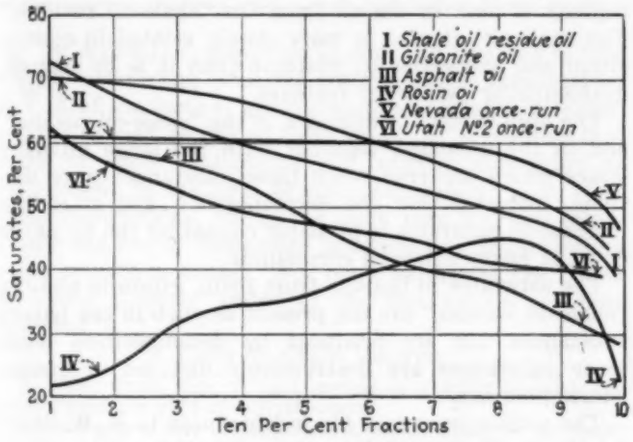

FIG. 1—SATURATION CURVES

Except in the formation of "additional saturates," the rosin bears little resemblance to the "shale-oil residue." The rosin on distillation formed small percentages of gas and coke, but a very high percentage of water. Water was also formed in both distillations of the rosin oil, but did not readily separate from the oil, and measurement was not possible except by redistillation or after standing for months in a warm place.

Petroleum residues are similar to the "shale-oil residue" in content of malthenes, but the petroleum malthenes are higher in saturates and as a rule petroleum yields less fixed carbon on distillation. Further discussion relative to these materials is at present inopportune, since no data have been obtained in regard to the amounts of gas, coke and "additional saturates" formed and nitrogen lost in destructive distillations of petroleum residues at atmospheric pressure. It has not been possible to include these distillations in the experimental work of this paper, but a study of this kind is desirable, since the results might give information regarding the truth of the hypothesis suggested by the author in a former paper[12] that "the 'additional saturates' are formed by decomposition of unstable nitrogen constituents" and might also give light on the correctness of Richardson's hypothesis[13] as to the origin of gilsonite and grahamite from petroleum. It is probable that gilsonite and the many varieties of bitumen found in and near the State of Utah may prove to be more closely related in composition to shale materials than to petroleum.

Both Richardson[14] and Mabery[15] have pointed out the differences between gilsonite and grahamite. These differences apply also to the "shale-oil residue" and grahamite. The grahamite has a higher gravity, lower content of malthenes, a much higher content of carbenes, and yields on distillation less oil[16] but more fixed carbon and residual coke than the "shale-oil residue." The large proportion of saturates noted by Mabery[16] in oil from grahamite and the small amount of saturates found by Richardson[17] in this bitumen suggest that grahamite on distillation may yield an oil of much higher saturation than gilsonite and the "shale-oil residue."

[11] "Destructive Distillation," p. 13.
[12] CHEM. & MET. ENG., vol. 26, No. 9, p. 399, March 1, 1922.
[13] *J. Ind. Eng. Chem.*, vol. 8, p. 494.
[14] "Modern Asphalt Pavement," 1910, p. 549, *J. Ind. Eng. Chem.*, vol. 8, p. 494.
[15] *J. Am. Chem. Soc.*, vol. 39, p. 2024.

PROBABLE ORIGIN OF DISTILLATION PRODUCTS

Mabery's statement that "while there is considerable decomposition in the initial distillation, it seems probable that heavier saturated hydrocarbons and solid paraffines form a considerable part of the natural bitumen (gilsonite) . . ."[15] is not in harmony with the very low percentages of saturates found by Richardson[18] in gilsonite and verified by the writer in the gilsonite studied in this paper. This gilsonite contained 6.6 per cent or less of saturates and the gilsonite oil contained 29 per cent of "additional saturates." There can be no doubt that large quantities of saturates are formed in the distillation of the gilsonite and the "shale-oil residue." It is probable that diminished pressure would decrease the decomposition of these bitumens on distillation and possible that grahamite may undergo a large amount of decomposition on distillation, even though the pressure is greatly reduced. Such behavior would account for the large amount of unsaturates found by Mabery in the gilsonite oil and for the rather high percentage of saturates noted by him in the grahamite oil. It is not reasonable that coal, grahamite and oil shale,

[16] Mabery, *loc. cit.*
[17] *Loc. cit.*
[18] *Loc. cit.*, p. 2022.
[19] *Loc. cit.*, p. 494.

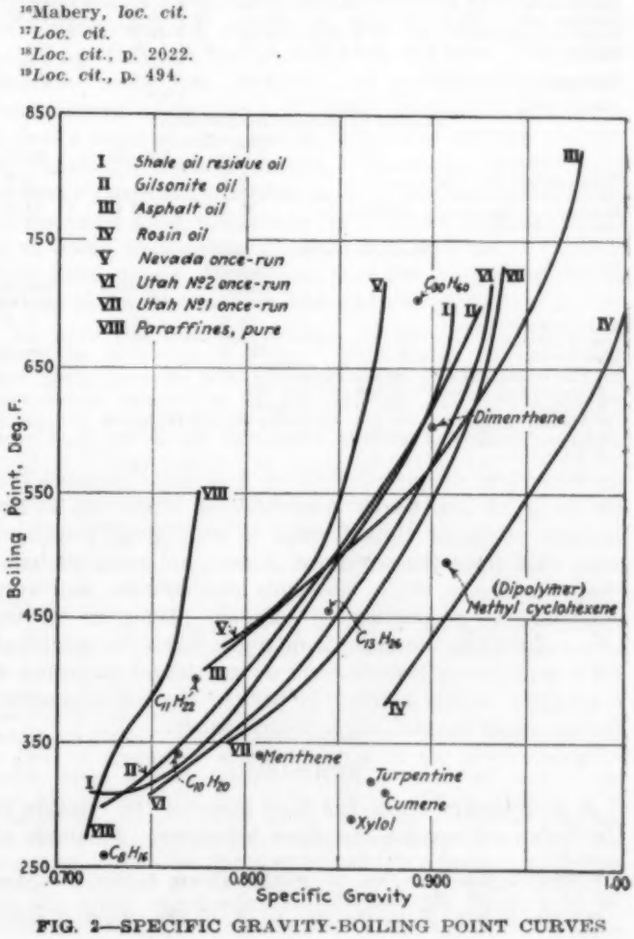

FIG. 2—SPECIFIC GRAVITY-BOILING POINT CURVES

which contain but very small amounts of materials soluble in petroleum ether, can contain paraffines in considerable quantity. The saturated and unsaturated oils produced by destructive distillation of these materials and of the gilsonite and the "shale-oil residue" must be formed by decomposition of heavy unstable materials, other than saturates, in the parent substances. It is evident from the decomposition of the crude shale oils already studied[7] that the percentage of saturated oil increases as the decomposition of the unstable material proceeds and is a maximum only when the decomposition of the unstable shale bitumen is complete.

Both the "shale-oil residue" and the gilsonite contain over 2 per cent of nitrogen. On distillation these materials lose 72.8 per cent and 76.3 per cent respectively of the original nitrogen, and the losses are attended by the formation of 23.3 per cent and 29 per cent respectively of "additional saturates." This is further evidence to that already given[8] that the unstable heavy materials, which are readily removed from the crude oils by sulphuric acid and which form "additional saturates" on decomposition, are composed largely of nitrogen compounds. On decomposition the nitrogen forms ammonia and soluble organic bases and a portion remains as a constituent of some of the lighter stable oils. Small quantities of water are noticeable in the decomposition

TABLE IV—SUMMARY OF DATA ON "SHALE-OIL RESIDUE" AND RELATED BITUMENS

	Asphalt	Petroleum Residues	Shale-Oil Residue	Gilsonite	Grahamite
Gravity	1.06–1.42	0.926–1.14	1.015	1.011–1.057[2]	1.157–1.184[2]
Saturates, %	8.0–29.0	41–79	10.7	5.3[2]–6.6	0.3[2]
Soluble in CS_2	40–98	99.6–99.9	99.8	99.0–99.9	94.–98
Malthenes, %	43–72	60–98	83.6	24.5–55.3[2]	0.4–38.8[2]
Carbenes, %	17.5	.....	0.26	0–0.4	55–80[1]
Residual coke	33.3[6]	.....	36.2	10.0–16.7[2]	40–51.4[2]
Fixed carbon, %	10.8–17.9	1.8–10.0	10.6	3.3–26.0[1]	35–53[1]
Sulphur, %	4.0–8.3	0.6–4.5[5]	0.37	0.26–1.3[4]	2.07[3]
				0.02[3]	0.9–2.0[1]
Nitrogen, %	0.5–1.0	.....	2.05	0.3–2.59	0.2[6]
				1.05[3]	

Products of Destructive Distillation

	Shale-Oil Residue	Gilsonite	Asphalt
Water, per cent by weight	0.2	1.0	0.0
Oil, per cent by weight	53.2	54.5	53.3
Residual coke, per cent by weight	36.2	27.8	33.3
Gas, by difference	10.4	16.7	13.4

Effects of Destructive Distillation

	Shale-Oil Residue Per Cent	Gilsonite Per Cent	Asphalt Per Cent
Additional saturates	23.3	29.0	5.8
Loss of nitrogen	72.8	76.3	.....
Loss of bitumen	46.8	45.5	46.7

[1] Richardson, "Modern Asphalt Pavement," 1910.
[2] Richardson, *J. Ind. Eng. Chem.*, vol. 8, p 494.
[3] Mabery, *J. Am. Chem. Soc.*, vol. 39, p. 2,024.
[4] William C. Day, *J. Frank. Inst.*, vol. 140, p 221, vol. 145, p. 476.
[5] Cross, "Handbook of Petroleum, Asphalt, etc.," No. 15, 1919.
[6] Table II.

products of the heavy materials of shale oils. The amount of water thus formed is very small compared with that from the rosin and it does not seem probable that the heavy shale materials can contain any very considerable proportion of oxygen. Whether in the crude shale oils the organic nitrogen bases are combined with acidic constituents such as are found in resins is a question whose solution is beyond the limits possible for the experimental work of this paper.

Summary

A preliminary study has been made of the relation of the "shale-oil residue" to other bitumens. A sample of gilsonite proved to be almost identical in properties to the "shale-oil residue" and the products obtained from these substances by destructive distillation were also similar in quantity and properties. A destructive distillation of asphalt yielded less oil and a much lower percentage of "additional saturates" than the "shale-oil residue," but the distribution of the saturates in the fractions of the oils is similar. On distillation rosin formed "additional saturates" equal in quantity to the yield from crude shale oils, but the decomposition was accompanied by the formation of a much larger quantity of water and the distribution of the saturates in the fractions of the oil was the reverse (last fraction excepted) of that in the oil from the "shale-oil residue." The shale-oil bitumen is more closely related in composition and properties to gilsonite than it is to asphalt, grahamite or petroleum residues.

The high content of nitrogen in the "shale-oil residue" and in the gilsonite, together with the large nitrogen losses which occurred when these substances were distilled, indicates that the decomposition and attending increase in saturates is probably caused by the breaking down of heavy nitrogen compounds.

The saturates in the oils from rosin, gilsonite and the "shale-oil residue" are not present as such in the parent substances, but are produced by decomposition when these substances are destructively distilled at atmospheric pressure.

The author expresses his indebtedness to R. W. Boyd for the distillation of the rosin and the rosin oil.

Golden, Col.

[7] CHEM. & MET. ENG., vol. 24, p. 876. CHEM. & MET. ENG., vol. 26, No. 9, p. 398, March 1, 1922.

[8] CHEM. & MET. ENG., vol. 26, No. 9, p. 399, March 1, 1922, Table I.

"Oxide Pox" Among Zinc Oxide Workers

The effects of zinc oxide dust in causing a troublesome dermatitis were observed recently in a zinc oxide manufacturing plant in the course of an investigation of the effects of inhaling zinc oxide dust. In the plant investigated the workers called the disease "oxide pox," because of its similarity to the eruption of smallpox.

Of the seventeen men examined who are exposed to the oxide dust in the bag-room and packing departments all but three gave a history of having had attacks of "oxide pox" and eight were suffering from the affection at the time of the investigation. The men had been employed for varying periods so that the length of employment did not seem to play any part in the occurrence of the disease. "Oxide pox" is caused by a clogging of the sebaceous glands with zinc oxide and subsequent bacterial infection. The disease is most prevalent in summer, although six of the men claimed they were affected regardless of the season but that it was more troublesome in the summer months. The eruption is accompanied by intense itching and usually persists for a week or 10 days, gradually subsiding and drying up, and is then followed by a slow but marked peeling of the skin. The cases studied showed no signs of systemic disturbances and no time was lost from work, although the disease caused considerable discomfort.

Zinc oxide is recognized as a non-toxic substance in which adulterating substance is so small as to be harmless, but is capable of acting as a mechanical conveyor of bacteria. It was found to be the general opinion among the workmen that the occurrence of the disease depends entirely on personal cleanliness and if daily baths are taken no trouble is experienced. Special work clothes of a close weave of cloth, made to fit snugly at neckband, wristband and ankles, should be worn to prevent the dust from coming in contact with the body.

Grain Growth and Recrystallization in Metals—III—Underlying Causes

Growth-Force of a Crystal Depends Principally Upon Small Average Grain Size and Large Contrast in Sizes—Recrystallization Is Grain Growth of Fragmented Crystals, No New Nuclei Appearing Until a New Crystalline Phase Arrives*

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MATERIAL presented in previous portions of this article has consisted entirely in the presentation of the facts of grain growth and of such generalizations as may be drawn from them. It is possible that some of these statements will require correction or amendment in the light of more accurate or more complete observations, but in the main they are well established and are of immediate practical use in controlling grain growth in metals. For ready reference, the "Laws of Grain Growth" coded in the last article are here repeated.

Laws of Grain Growth

1. The grain size of cast metals is usually smaller the more rapid the rate of solidification.
2. The grain size in cast metals which undergo no phase change in the solid state cannot be changed appreciably by heating below the melting point.
3. Grain growth in the solid state may occur in (*a*) worked metals, (*b*) compressed powders, (*c*) electrodeposited metals, (*d*) in iron when it changes allotropic form and (*e*) in alloys in which a new phase is formed in the solid state.
4. The recrystallization temperature is lower (*a*) the greater the amount of deformation, (*b*) the smaller the grains prior to deformation, (*c*) the purer the metal, (*d*) the lower the temperature at which the deformation is effected and (*e*) the longer the time of heating.
5. In any given metal the grain size after complete recrystallization is normally smaller the lower the recrystallization temperature.
6. Above the recrystallization temperature the grain size is normally greater the higher the temperature and the longer the exposure.
7. The higher the temperature the more rapid the grain growth. At a temperature near the melting point a few seconds is often sufficient to produce grains which may not change further on extended exposure.
8. Certain conditions of non-uniformity sometimes give rise to the formation of abnormally large grains. This is called germination.
9. The non-uniformities giving rise to germination are: grain size contrast, strain gradients, temperature gradients, concentration gradients, and obstruction gradients.
10. The presence of foreign matter or a second phase introduces mechanical obstruction to grain growth. The resistance to growth increases as the quantity of foreign matter or other phase increases and as the particle size decreases.
11. The presence of a certain amount of obstruction matter promotes germination.
12. The higher the germination temperature the larger will be the grains and the quicker will they form.
13. The more rapid the heating through the germinative temperature range, at least within limits, the finer will be the grain size.

It is also desirable to have a conception of the fundamental causes underlying these phenomena, as by this means the various facts can be more easily correlated and new facts more rapidly discovered. Many contributions have been made to the literature on grain growth and no small part has been devoted to the theoretical aspects. Naturally many of the ideas have been discarded and certain ones have gained a sufficient following to warrant their general acceptance by metallographists. In the remainder of this article the authors will put forth a conception of the fundamental causes of grain growth consistent with the observed facts and with modern developments in molecular physics. While some of the ideas will be recognized as new, the conception as a whole is quite in accord with generally accepted theory on grain growth.

Possible Causes of Grain Growth

Grain growth obviously results from the tendency of matter to assume the form of greatest physical stability, which is the form of least energy. The crystallization of metals from the liquid state is always accompanied by an evolution of heat, representing the loss in the kinetic energy of the atoms incident to their fixation in the rigid crystal lattice. The atoms at the surface of a liquid or solid body are less subject to the attraction of their neighbors than are the atoms in the interior. They are therefore more free to move and consequently possess more energy of motion. A "free" surface of any body is thus a locus of extra energy, known as surface energy or sometimes surface tension. There is, therefore, a tendency for small particles, such as drops of a liquid or crystals of a solid, to unite to form larger particles, since in so doing they diminish their surface area and hence their total energy. It follows that the most stable form for any piece of metal would be a single crystalline grain.

To have the smallest possible surface area this grain should be spherical in shape. This would not, however, necessarily give the minimum surface energy, because of the geometrical properties of the crystal. The most stable shape for a crystalline substance is often an idiomorphic form built up of the natural crystal faces. On the other hand, it is well known that small particles of certain crystalline constituents in a metallic aggregate tend on long heating to assume a spherical form. The question is not of great importance here, and may be dismissed by saying that the most stable form of a metallic crystal is that of least surface energy, which will probably be either idiomorphic or spherical.

There has been considerable confusion in the literature on grain growth arising from a lack of distinction between true or stable equilibrium and metastable equilibrium. Some have considered that the ultimate stable condition of a piece of metal is not a single crystal, simply because such specimens are very rarely encountered and then only as a result of rather special manipulation. Such a conclusion is just as absurd as a conclusion that the gravitationally stable form of the earth's surface consists of mountains and valleys, and for the same reason. Grain growth is a process involving inertia which must be overcome just as the friction of the material composing a mountain must be overcome before the force of gravity can level it with the plain. Similarly the fact that even after prolonged annealing above the recrystallization temperature grains may be found having jagged or irregular outlines does not in any

*Part I, on Definitions, was published in CHEM. & MET. ENG., vol. 26, No. 8, p. 343, Feb. 22, 1922; Part II, on Experimental Data and General Laws, vol. 26, No. 9, p. 402, March 1, 1922.

way disprove that smooth outlines would represent a condition of greater thermodynamic stability.

Obviously any roughness on the surface of a crystal is a source of increased surface energy and hence diminished stability.

If a crystal is subjected to an external load below its elastic limit, it becomes temporarily deformed or distorted. On release of the load the crystal returns to its original form. The deformation of the crystal by the external load requires an expenditure of energy which is stored in the crystal itself and manifested by its ability to return to its original shape, doing work as it returns. An elastically deformed crystal thus contains more energy than a similar crystal free from stress and distortion, and is therefore less stable thermodynamically.

We have now considered briefly all of the factors which, according to our present knowledge, may influence the stability of a crystal—namely, size, form, surface and distortion. The most stable form for a solid metal is a single crystal, spherical or idomorphic in shape, of smooth surface, and free from any distortion of its space-lattice. All solid metals must tend to assume this condition.

Conditions for Grain Growth

Any piece of metal which consists of more than one grain must possess a tendency for grain growth which is greater in proportion to the departure from the condition of maximum stability. We may for convenience designate this tendency "growth-force." Grain growth will take place whenever the growth-force is sufficient to overcome the opposition to growth. Grain growth takes place by a process of boundary migration which involves the gradual transfer of atoms from the lattice of one grain to that of the adjacent grain. Whether or not this transfer takes place through a layer of amorphous grain boundary metal, it requires a certain degree of atomic mobility of *temperature* for its accomplishment. There is usually present in metals some form of obstruction which mechanically interferes with grain growth, such as thoria in tungsten and pearlite in steel. This obstruction may be so great that it prevents grain growth altogether. In any case with a given growth-force the presence of obstructing materials raises the temperature required for grain growth.

It has been suggested that in order for one grain to absorb another it is necessary that the orientations of the two grains be very similar. Some observers have reported, however, that the relative orientation of the grains has no apparent effect on growth. It may well be imagined that although similarity of orientation might facilitate the process of growth, this very condition would also decrease the force tending to cause growth. In any event, there is not sufficient evidence to justify serious consideration of relative orientation as a factor in grain growth.

We may take as a sound foundation for the development of a theory of grain growth the proposition that the impetus of growth-force is due to a condition of thermodynamic instability and that when such a condition exists growth will take place whenever the temperature and obstruction factors permit. The factors affecting the stability of the grains of a metal and hence the growth-force have been indicated (size, shape, surface and distortion). The relative importance of these factors will now be considered more fully.

Shape and Surface of Grains

There are frequently found even in unstrained metals grains of such elongated or extended shape that the ratio of surface area to volume is abnormally high for grains of that size. Presumably such grains are less stable than grains of the same size but of more nearly equiaxed shape, which therefore tend to grow at the expense of the former. Actual observation indicates, however, that such differences in shape constitute a relatively minor factor in grain growth.

Rosenhain has observed that in deformed lead in which grain growth was occurring the outlines of the grains were ragged, while in cast lead, in which grain growth could not be produced by heating, the outlines of the grains were much more smooth. He considered that the ragged boundaries represented a condition of greater surface energy, hence less thermodynamic stability, and consequently a greater tendency for grain growth. This may account in part for the fact that grain growth occurs in worked metals but not in cast metals. General observations on the effect of grain outline or surface on grain growth phenomena are lacking, however, so that this factor cannot be incorporated as basic in a theory of grain growth.

Grain Size the Important Factor

The tendency of metals to reduce their store of energy by increasing their grain size is the factor which has probably been considered the principal cause of grain growth. There are, nevertheless, many who do not regard this as furnishing an adequate explanation of all the phenomena involved. The authors believe that grain size, considered both absolutely and relatively, is the chief factor determining the growth-force or tendency for grain growth to occur, and that it furnishes the basis for a completely satisfactory theory of grain growth.

A crystalline grain is to be regarded as an organized structure having a definite power to hold its atoms in their positions in its space-lattice, and to attract neighboring atoms into its lattice. This power is due to the cumulative effect of the directional force fields of the atoms composing the grains. The exact nature of these force fields is not known, consequently the manner of their linkage is unknown. It is held by some students of atomic and molecular physics that the attractive force of an atom does not extend to a distance of more than two or three atom diameters, in which case the orienting power of a crystal would be very little affected by its size when such a crystal contained more than about six atoms across its smallest diameter. The authors believe that the influence of the atoms within a crystal upon its orienting power extends to a much greater distance. In any event, it is certain that large crystals or crystalline grains do possess that property which has here been called "orienting power" to a greater extent than do similar crystals of smaller size.

Many examples of this general fact are known. It is known that the solubility of many salts in water is greater the finer the particles of the salt. Some figures for the solubility of calcium sulphate in water are as follows:

	Diameter of Grains	
	2 μ	0.3 μ
Solubility per liter.....	2.08 g.	2.56 g.

That is, the concentration of a saturated solution in equilibrium with an excess of the solid salt is greater the smaller the particles of the solid. This can mean only that the small particles are less capable of attracting atoms or molecules from solution than are the larger particles. The actual observed effect upon the solubility

is small, and is smaller the larger the size of the particles of excess solid. It is sufficient, however, to cause the size of the particles or crystals to increase by a process of solution and redeposition. Chemically speaking, the solution is unsaturated with respect to the smaller crystals but supersaturated with respect to the larger crystals. The former therefore dissolve and the material thus removed precipitates upon the larger crystals.

Entirely similar phenomena are observed in metals. The most familiar example is that of cementite (iron carbide) in iron. If a steel containing, say, 0.90 per cent carbon is hardened by quenching in water from about 760 deg. C. and then tempered by reheating to about 400 deg. C., it is obtained in a structural condition which is metallographically termed "troostite." Although the structure of troostite is irresolvable under the microscope, it is quite certain that it consists of submicroscopic crystalline particles of cementite imbedded in ferrite (iron). Now, if the steel is heated for several hours at a temperature of about 700 deg. C., the cementite particles become visible, and on continued heating can be observed to grow. They are not directly connected with each other in any way, so the transfer of material from one particle to another must take place through the ferrite. The smaller particles dissolve in the ferrite until a solid solution is formed which is supersaturated with respect to the larger particles. Precipitation then occurs on these larger particles, with the net result that they grow at the expense of the smaller particles. Physically this means that the larger particles have stronger attractions for their constituent atoms than do the smaller particles.

The general principle here illustrated is that in an aggregate of grains of various sizes, the larger grains tend to grow at the expense of the smaller. If we assume a condition in which all of the grains are of exactly the same size and similar in other respects, there is a balanced condition with no opportunity for grain growth, even though the tendency for growth is present, due to the fact that the thermal stability of the aggregate would be increased by an increase in grain size. The grains all possess equal powers of orientation, however, so that there is no resultant growth-force. Grain growth thus depends on a *difference* in grain size, or on what may be called grain size contrast.

While the orienting power of a crystal probably increases with its size almost indefinitely, there is ample evidence that the rate of increase is most rapid when the size is very small, and may become practically negligible for larger crystals. Thus the effect of crystal size on the solubility of salts is appreciable only for relatively small crystals. Similarly the growth of cementite particles in steel becomes very slow after they have reached a diameter of about 0.00004 in. The actual extent to which such growth proceeds is determined largely by the temperature, since a higher temperature is necessary to facilitate growth when the growth-force is small.

Meissner[1] has recently determined the effect of particle size upon the melting point of myristic acid and found that this temperature is lowered about 0.5 deg. C. by decreasing the particle size from 10 μ to 0.8 μ. This phenomenon is another illustration of the fact that very small particles of solid have less attraction for their atoms or molecules than do larger particles.

The growth of certain grains in a metallic aggregate at the expense of others may be regarded as a competitive process. At the boundary between two adjacent grains there is a competition for the surface atoms, or the atoms of the essentially amorphous cement which probably surrounds the grains. The grain which has the greater orienting power attracts atoms from the other grain, and thereby grows. Drawing an analogy with vital processes, we may say that the grains have definite powers of attack and defense, and that the stronger grains feed upon the weaker. Power of attack and of defense is of course synonymous with that we have called orienting power. Orienting power depends upon grain size. The tendency for growth or the growth-force depends upon a difference in orienting power. This difference increases with the disparity in grain size and with the smallness of the smaller grain.

To sum up the above discussion, the causes favoring grain growth are:

1. Small grain size.
2. Grain size contrast.

The importance of grain size contrast as a cause of growth has been questioned by some students of the subject and has recently been emphatically denied by Carpenter and Elam[2] as a result of observations purporting to show the absorption of large grains by small ones. These observations are open to two serious objections:

1. They were made on plane sections, and grains which appear small on such a section may actually be very much larger. Given any two adjacent grains of which one is only moderately larger than the other, it will usually be possible to pass through them a plane on which the sections of the grains are reversed in size. It is therefore a mathematical probability that when the differences in grain size are not great there will be on any section including a large number of grains some cases where the larger grains appear to be the smaller. In the discussion of Carpenter and Elam's paper this objection was raised and has not been satisfactorily answered.
2. The alloy of tin and antimony used in their experiments is very soft and susceptible to strain in the polishing operation. It is therefore quite possible that an observed large grain apparently intact had actually been broken up into very much smaller fragments. There is no reason why a small unstrained grain should not absorb a large strained grain; this is in fact more probable than the reverse phenomenon.

The present authors do not know of any well-established case of the absorption of a large unstrained grain by a smaller grain. Even if some such cases should be established, however, they would merely show that some of the other factors which have been mentioned may occasionally overbalance the grain size contrast factor, and would furnish no basis whatever for the dogmatic statement that grain size contrast is not important as a cause of growth. On the other hand there is abundant positive evidence of the strongest kind that the grain size contrast principle is important and usually dominant.

Temperature and Obstruction Limiting Conditions

The presence of a growth-force due to the causes just described will not result in grain growth if the temperature is too low or if the mechanical obstruction to growth is too great. The factors are mutually interdependent. With given conditions as to mechanical obstruction, grain growth will occur at a lower temperature the greater the growth-force; or conversely, the less the growth-force the higher the temperature required to bring about grain growth. With a given growth-force the temperature required to bring about growth increases with the amount of mechanical obstruction. Thus grain growth is controlled by three factors: (1) *grain size;* relative and absolute, which determines

[1] "The Influence of State of Division on the Melting Point," Meissner, *Z. anorg. Chem.*, vol. 110, pp. 169-186, March 12, 1920.

[2] "Crystal Growth and Recrystallization in Metals," Carpenter and Elam, *J. Inst. Metals*, 1920, No. 2.

the growth-force or tendency for growth to occur; (2) *temperature*, which is equivalent to atomic mobility and determines whether the growth-force can overcome the rigidity of the metal; and (3) *obstruction*, which mechanically hinders and sometimes entirely prevents grain growth.

Metastable Equilibrium

Grain growth may fail to occur or having started may come to a halt as a result of unfavorable conditions in respect to any one of these three factors. The growth-force may be so small that even in the purest metal grain growth will not occur at any temperature short of the melting point. This is the condition that ordinarily obtains in metals solidified from the molten state and not subjected to any form of deformation. It is quite natural that this should be the case, in view of the rapidity of grain growth at temperatures near the melting point. The short time which elapses during even the most rapid solidification is sufficient for the growth-force to be reduced by the process of grain growth to such a point that no further growth will take place at lower temperatures even when maintained for long periods of time.

It is quite common to find fairly marked grain size contrast in cast metals in which it is not possible to bring about grain growth. A common example is found in ingots at the junction of the columnar grains which grew out from the mold walls with the equiaxed grains in the central portion of the ingot. Such observations have been considered by some to be inconsistent or even incompatible with the grain size contrast principle. While granting that the failure to obtain grain growth under these conditions may be influenced by the shapes of the grains or their contours, the present authors consider that the grain size principle alone is sufficient to account for the facts. While the grain size contrast may in some of these cases be considerable, the actual grain size is never very fine, in comparison to the grain size of worked metals. It is this general coarseness of grain in cast metals to which may be attributed their failure to exhibit grain growth on heating at temperatures below the melting point.

There is reason to believe that grain growth, in the solid state, does occur in cast metals during the process of solidification. An example was described earlier in this article[3] of a tungsten rod, the axial portion of which had been melted by an electric current and then allowed to resolidify. It was pointed out that whereas we might expect to find the grains formed during resolidification starting from the unmelted grains as nuclei, what we do find in fact is that the new central grains are vastly larger than the old grains in the outer rim, extending from this rim to the center of the rod. It is quite certain that in the initial stages of the resolidification the new grains actually did form upon practically all of the old grains in the rim and began to grow inward. The final result indicates very strongly that some of the larger grains absorbed their smaller and already solidified neighbors.

Upon annealing worked metals under certain conditions it has been shown that the final grain size depends very largely upon the annealing temperature. For the lower annealing temperatures the grain size depends to a large extent upon the degree of prior strain hardening, the rate of heating, time of holding at heat, etc., but at higher temperatures the effect of such variables is greatly reduced, especially if the metal is fairly free from growth obstruction, so that the annealing temperature is the principal factor determining the grain size. In other words, there is an apparent equilibrium grain size for each temperature. As the temperature of the metal is raised, grain growth takes place until the growth-force is reduced to a point where it can no longer cause growth under the existing conditions of temperature and obstruction. The metal is then in a state of metastable equilibrium as regards grain growth. In this condition the grains are usually fairly equal in size. Consequently, the normal grain growth which takes place on heating a worked metal consists merely in a change of structure toward the condition of metastable equilibrium for the temperature of the anneal.

Recrystallization Is Grain Growth

The replacement of a single strained grain by a number of unstrained grains of various orientations suggests that new crystalline nuclei are formed during the process of recrystallization. We know, however, that the strained grain has within it an abundance of nuclei in the form of fragments produced by deformation. It is more logical to suppose that recrystallization consists in the growth of some of these grain fragments to visible size than that entirely new nuclei are formed. A strained grain may be regarded as an aggregate of a large number of crystalline fragments each equivalent to a very small grain. This aggregate is not the same as an equal number of unstrained grains of similar size in annealed metal, since the boundary conditions are undoubtedly different. It is probable, too, that the change in orientation from fragment to fragment is very slight as compared with that from grain to grain in an annealed metal. In spite of such differences, the strained grain is actually an aggregate of smaller grains which, because of their small size and the size contrast unavoidably present, are especially susceptible to growth on heating.

When an annealed metal is plastically deformed, the action is most severe near the grain boundaries. The grain fragments formed are therefore smallest in these regions. Small grain size is conducive to growth at low temperatures, and it is therefore quite natural to find, on heating a strain-hardened metal under conditions of time and temperature which produce only partial recrystallization, that the new grains are first observed at the old grain boundaries. Long heating at low temperature might cause these first grains, by reason of their advantage in size, to absorb all of the grain fragments in the central portion of the old grain. In such a case the new grains could not possibly be smaller in diameter than one-half the least diameter of the strained grain. If the metal is heated quickly to a temperature well above that of incipient recrystallization, fragment growth will take place substantially at the same time in all parts of the old grain. This is probably what happens in ordinary industrial annealing.

An objection to this view that recrystallization is merely submicroscopic grain growth[4] is found in the belief held by some that during plastic deformation the grain fragments retain substantially their original orientation. It is a fact that the new grains which form from a strained grain upon proper heating have practically random orientations, all of which may differ from that of the original grain. If these new grains are held to have grown from the fragments of the old grain, then it must be considered that the fragments which acted as nuclei also possessed random orientations.

In view of the fundamental importance of the question, some experiments were made by means of X-ray analysis to determine whether or not new orientations are produced by

[3] Chem. & Met. Eng., vol. 26, No. 9, p. 403, March 1, 1922.

[4] "Recrystallization of Cold-Worked Alpha Brass on An Mathewson and Phillips, *Trans.*, A.I.M.E., vol. 54, p. 608

deformation. The methods and results have been presented fully in a recent issue of this journal[1] and will not be repeated here. The evidence was conclusive that new orientations *are* produced by the simplest types of deformation, such as rolling or pressing. A stricking illustration of change of orientation produced within a grain by twisting is shown in Fig. 1, reproduced from the same article. The definite proof that the grain fragments produced by the deformation of a single grain actually have mixed orientations removes the only valid objection to the view that recrystallizations is merely grain growth.

The actual amount of grain growth involved in the process of recrystallization is remarkably great considering the small change in temperature necessary for its accomplishment. The average grain diameter in a pure metal or solid solution alloy which has just been completely recrystallized is generally not less than about 0.0005 in. We have as yet no means of accurately measuring the fragment size in a strain-hardened metal, but we know that it is very small, since it requires only a slight deformation to produce slip bands upon a polished metal surface so close together that they cannot be resolved under the microscope. The much more severe deformations commonly effected in cold-working operations must produce fragments with diameters on the order of 0.000001 in. The increase in grain diameter during recrystallization is then about 500 to 1. In terms of grain volumes the increase is 125,000,000 to 1. The same ratio represents the decrease in the number of grains in a given volume of metal. Expressed in a slightly different way, 125,000,000 grain fragments unite during recrystallization to form one unstrained grain. The temperature change required to bring this about for ordinary periods of heating is usually not over 150 deg. C.

If a similar ratio of grain growth would be effected in the recrystallized aggregate whose grains average 0.0005 in. in diameter, the new grains would be ¾ in. in diameter. This is an enormous grain size for any normal worked metal. Such grain sizes are frequently obtained under germinative conditions as described in the second part of this article, but seldom as a result of normal grain growth, even on raising the annealing temperature from that of recrystallization to just under the melting point. This suggests that the commonly observed recrystallization normally takes place under what might be called germinative conditions.

We have seen that the recrystallization temperature is higher the less the previous strain-hardening. As a cause of grain growth, strain is merely a mechanical process of grain refinement. The greater the degree of strain the smaller are the grain fragments produced and consequently the lower the temperature at which grain growth, or recrystallization, will take place.

It is very important here and subsequently to keep clear in mind the fact that small grains or fragments facilitate growth because they are easily absorbed. In an aggregate of grains which are strained to various extents, the grains which are *least* strained are in a position to grow by feeding upon their more severely strained—i.e., fragmented—neighbors. It has been a common mistake to consider that, since strain leads to grain growth, the grains which are most strained are the ones which grow.[2] This fallacy seems to be based upon a false conception of the energetics of the case. It is held that energy is required to impart the power to grow, and that this energy must be stored in some way in the grain. The strained grain is therefore regarded as the one endowed with the power of growth. Actually the conditions are the exact reverse. The unit which does the growing is the grain of greatest thermodynamic stability and hence *least* energy content. The logic of this is apparent on considering the conditions on the solidification of a metal from the molten state. The solid, unstrained grains feed upon the molten phase, which has the higher energy content.

Grain Growth in Electrodeposits

According to the conditions of deposition, electrolytic metal may be obtained in a soft, coarse-grained variety or in a hard form whose structure is so confused that Beilby was led to the conclusion that it is amorphous. Any gradation between these two extremes may also be obtained. If the harder varieties are annealed, they are found to have "recrystallized" very much after the manner of strain-hardened metal. Beilby attributed this to the formation of crystalline nuclei in the amorphous metal. Later researches have shown that the hard electrodeposited metal is predominantly crystalline. There is little doubt that the hardness and recrystallizing properties are due to a very small grain size, just as they are in strain-hardened metal. It is sometimes said that the metal is deposited in a "state of strain," which is correct if taken to mean a condition similar to that produced by plastic deformation. The essential feature in this state of strain is the great fineness of grain.

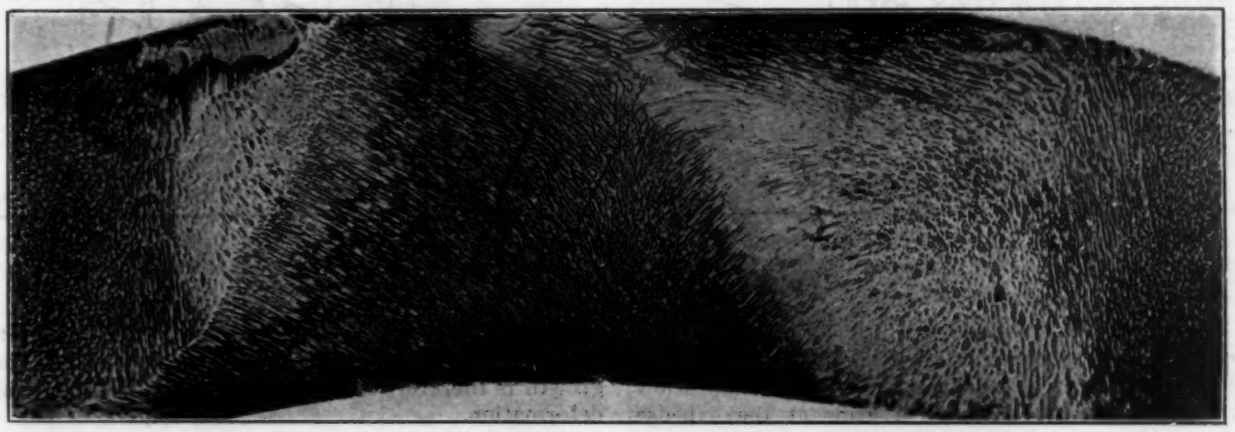

FIG. 1—SINGLE GRAIN IN TUNGSTEN WIRE, TWISTED COLD, POLISHED AND ETCHED. × 300. (TARASOV)

Metal Powders

Growth phenomena in metals formed from powders are exactly the same as in metals which have been melted and cast, although some writers would place them in a separate class. It has been erroneously stated that metal powders will not sinter to form a coherent mass when heated unless the pressure is sufficient to cause fusion at the temperature used. As a matter of fact, tungsten powder can be sintered below the melting point with no pressure except that due to its own weight. In fact it is very difficult to see how pressing a metal powder briquet could have any effect on the melting point except to raise it.

The particles of powder used in making tungsten briquets

[1] "Mixed Orientation Developed in Crystals of Ductile Metals on Plastic Deformation," Bain and Jeffries, CHEM. & MET. ENG., vol. 25, No. 17, Oct. 26, 1921, pp. 775-777.

are crystalline grains formed by reduction from tungstic oxide. It is possible that when strongly compressed some of these grains are plastically deformed. Any such strain-hardening should be removed before sintering takes place, as the sintering temperature is far above that of recrystallization. Sintering therefore consists in the union of unstrained grains accompanied by such boundary migration as is necessary, and usually by distinct grain growth. The grain size of a sintered ingot is never less than the size of the particles from which it was formed. Grain growth here is due to the usual causes—namely, grain size contrast and initial fineness of grain.

GERMINATION

Consider the conditions of grain growth in the hypothetical case represented in Fig. 2. The small grains are supposed to be nearly alike in size, but sufficiently different to give rise to a growth-force capable of causing grain growth when the metal is heated to a suitable temperature, which we will designate *T*2. The small grains in contact with the few large grains are similar to those in the interior of the fine-grained regions. The growth-force is therefore much greater at the boundaries of the large grains than in the interior of the fine-grained regions and the large grains will grow at a lower temperature, *T*1. Now suppose the metal is heated to a temperature above *T*1 but below *T*2. The few large grains will grow at the expense of the small grains until the latter are entirely absorbed and the large grains finally meet one another. Grain growth will then cease on account of the great resistance of the large grains to absorption, and the resulting condition is represented in Fig. 3.

Suppose that instead of being heated to between *T*1 and *T*2 the metal is quickly heated to a temperature above *T*2. The large grains will then begin to absorb the small grains as before, and at an even greater rate. At the same time, however, grain growth will take place among the small grains so that presently the large grains will no longer encounter the very small, easily absorbed grains, but will meet grains of more nearly their own size, which have developed in the fine-grained regions. Grain growth may then cease, leaving the metal as shown in Fig. 4.

Conditions commonly found in metals differ only in degree from the extreme case just described. There are always some differences in growth-force from point to point in the metal, and corresponding differences in the temperature at which grain growth will begin. If the metal is heated at a temperature sufficiently high to cause grain growth at some points but not high enough to cause general growth all through the metal, conditions are favorable for the development of large grains. However, the points at which early growth begins may be so close together that the grains developed are no larger than those normal to the temperature used. On the other hand, if the centers of growth are far apart, abnormal grain growth results. It is this preferential growth of certain grains to abnormally large size which is termed germination.

All kinds of plastic deformation unavoidably produce local, if not general, strain gradients. The strain or fragmentation varies from one region of the metal to another, from grain to grain, and in different portions of the same grain. The greater the strain the lower is the temperature at which grain growth will take place on heating. Hence in a uniformly cold-worked metal it is the points of greatest strain which act as the centers of germination. The grain size produced will be larger as these centers are farther apart. This condition is favored by *slight* deformation. Severe deformation tends to make the strain or fragmentation more nearly uniform throughout the metal, and brings the points of equal strain closer together. Abnormal grain growth is therefore most commonly obtained after mild deformation.

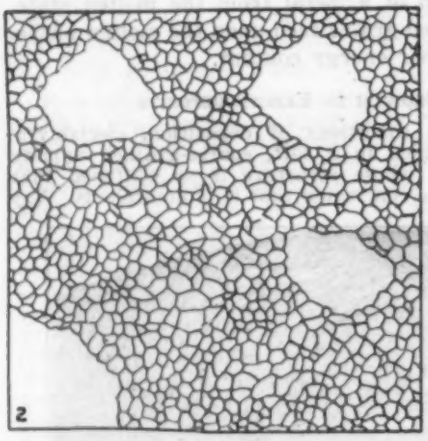

Fig. 2—Metal with moderate grain-size contrast.

Fig. 3—Same metal heated so that large grains grow.

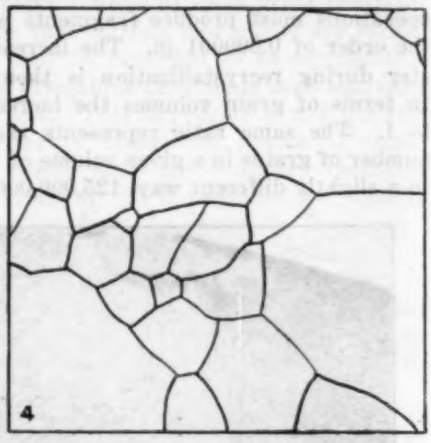

Fig. 4—Metal of Fig. 2 heated so that both sizes grow.

FIGS. 2 TO 4

Sauveur* found that a piece of mild steel stressed in tension to 40,000 lb. per sq.in. developed unusually large grains on annealing at 650 deg. C. If stressed to only 38,000 lb. per sq.in., this grain growth did not take place. This simply means that a stress of 40,000 lb. per sq.in. developed at a *few* points strain great enough to cause growth at 650 deg. C. in the time allowed. At 38,000 lb. per sq.in. the greatest strain produced was not sufficient to cause grain growth under these conditions. If a slightly higher temperature or a considerably longer time had been used, germination would have resulted in this case too. On increasing the stress to 42,000 lb. per sq.in. and maintaining the same conditions of annealing, grain growth occurred, but the grain size produced was comparatively fine. The centers of germination were in this case very close together.

When a metal is heated rapidly through the germinative temperature, the preferential growth of a *few* grains is prevented, because at the higher temperatures a very large number of grains are capable of growth. It might be said that they fail to attain abnormally large size because the competition is more keen.

The method of Ruder for producing excessively large grains in silicon steel and of Schaller for producing coarse-grain tungsten wire is based on a very simple type of

*"The Metallography and Heat-Treatment of Iron and Steel," A. Sauveur, pp. 265-271.

germination. The grain size of the starting material is sufficiently fine so that marked grain growth of the normal variety will occur at and above a suitable temperature which we will call *T*. The metal is then heated so that one region is above this temperature *T*, but the major portion is below this temperature. In the region heated above *T* grain growth will occur and there will be produced grains considerably larger than those in the colder or "inert" region, where no grain growth is taking place. (It appears that a certain amount of mechanical obstruction helps to prevent the coalescence of the small grains.) At the junction between the large grains of the growth region and the small grains of the inert region, conditions are ideal for the continued growth of the large grains at the expense of the smaller, exactly as in the hypothetical case described above in Fig. 2. The metal is now moved through the heated zone at a rate less than that at which the germinant

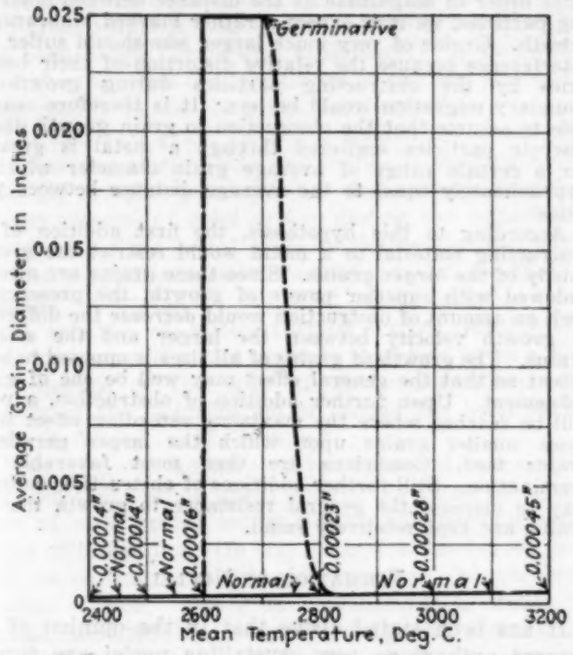

FIG. 5—GRAIN SIZE VS. TEMPERATURE FOR BRIQUETTED TUNGSTEN CONTAINING 0.75 PER CENT THORIA

grains can absorb the inert ones. Advancing the line of the growth temperature *T* at a faster rate would defeat the production of coarse grains just as does rapid heating through the germinative temperature.

The samples from which the "germinative" curve in Fig. 5[1] was obtained illustrates the effect of a temperature gradient nicely. When heated to an average temperature of 2,600 deg. C. by electric current and maintained for about 10 minutes, a few large grains formed about midway between the axis and surface of the rod. The hotter portion, near the axis, was composed of larger grains than the cooler surface portions. This shows that growth had taken place near the axis, but not at the surface. The few large grains were located at the boundary between the axial portion which may be called *growth range* and the surface portion or *inert range*. The inert grains were only inert in so far as concerns absorption by grains of their own size. Before heating, the grain size or particle size was uniform from axis to surface of the briquet. Of course there were local differences, but no general differences. A mean temperature of 2,600 deg. C. was proper to cause growth in the hotter axial portion, but not near the surface. There must then be a boundary between the growth and inert regions. The inert region is inert because of lack of grain-size contrast. Some grains in the growth range at the boundary between growth and inert regions increase sufficiently in size to absorb the inert grains and hence greatly increase in size. These grains are the "germinant" grains. The grains well within the growth range are small compared to the germinant grains, because of lack of grain-size contrast. When the germinant grains reach a size considerably larger than the grains in the growth region the latter are absorbed. The germinant grains then grow toward the surface and toward the axis, eventually producing a very coarse-grained structure as indicated in Fig. 6. The various grain sizes produced by varying the rate of heating through the germinative temperature range in these samples are in exact accord with the hypothetical case cited in Figs. 2 to 4. If the temperature is lowered a little below 2,600 deg. C., the germinant grains form nearer the axis, and with mean temperature a little above 2,600 deg. C. they form nearer the surface.

In the germinative conditions due to obstruction (Fig. 6) it was observed that the germinant grains formed first near the surface of the briquet in the 2.5 per cent thoria sample, about half way between the axis and surface in the 3 per cent thoria sample and near the axis in the 4 per cent thoria sample. The boundary between growth and inert ranges (germinative temperature) was thus at higher temperatures for the greater amounts of obstruction.

It is evident that the presence of a strain gradient in a piece of metal may lead to germination even on uniform heating. When the strain varies continuously as in Chappell's tapered bar,[2] there is some region where the degree of strain is just right to cause germination at the temperature used. After germination has taken place we have a condition similar to that described above —that is, a region of very large grains bordering on the unrecrystallized region of very small grain fragments. Grain growth will then proceed to some extent into this region, but will come to a halt when the strain decreases to a certain value. It should be especially noted that when there is a strain gradient germination may be obtained at any temperature within a rather wide range. When the strain is substantially uniform, there is only one temperature, or a narrow range of temperature, at which coarsening will take place. For this reason the chances of obtaining coarse-grained structures in industrial annealing or under high temperature service conditions is much greater when the strain is not uniform.

The important effect of the obstruction factor on germination has been pointed out. We have seen how germination in steel is most marked for a certain range of carbon content (0.04 to 0.12 per cent). In tungsten

[1] Reproduced from Fig. 26, Section II of this article, CHEM. & MET. ENG., vol. 26, No. 9, p. 408, March 1, 1922.

[2] Fig. 25 of Section II of this article, CHEM. & MET. ENG., vol. 26, No. 9, p. 407, March 1, 1922.

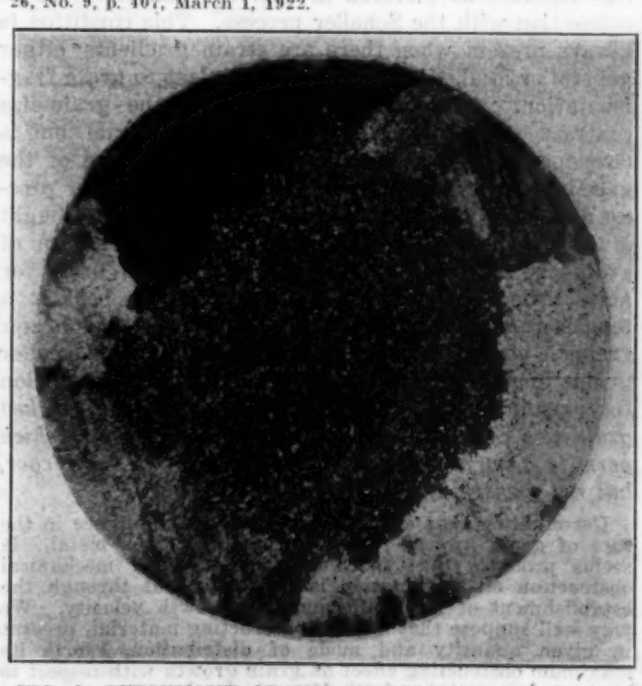

FIG. 6—GERMINANT GRAINS IN POSITION TO ABSORB SMALL GRAINS TUNGSTEN. × 25

heated under certain conditions the addition of a small amount of thoria refines the grain. More thoria causes germination, with the production of relatively enormous grains. Still more thoria inhibits growth to such an extent that no abnormally large grains are produced below the melting point. The same cycle has been shown to obtain on the solidification of a certain aluminum alloy under constant cooling conditions. The first addition of obstructing material refined the grain. A further addition caused marked coarsening, and a still further amount again refined the grain. It is not to be inferred from these examples that the progressive addition of obstruction always results in germination. Germination is in fact the exception rather than the rule. When germinative conditions *are* produced, however, the rule is that the progressive addition of obstructing material causes, first, refinement, then coarsening, then refinement. Often the first stage is not marked—that is, the first addition of obstruction may not produce a grain size noticeably smaller than in the pure metal. The germinative stage is most marked, and the return to normal grain size on the addition of more obstruction is of course equally apparent.

On analyzing the conditions under which these cases of germination occurred, we find that in Sauveur's uniformly stressed bars the coarsening resulted from local strain gradients, while in the tungsten briquets temperature gradients are responsible. In the solidifying aluminum alloy temperature and concentration gradients exist and there is unavoidably at any one time a difference in the size of the newly formed solid grains which corresponds to a strain gradient. These three cases therefore involve the principal factors which at various times cause germination. The fact that the effect of progressive additions of obstructing matter follows the same law in all cases indicates a similarity of mechanism.

Differential Growth Variety

Any case of germination in the solid state depends upon the existence at some stage of a marked grain size contrast as pictured in Fig. 2 or as described in connection with the Schaller process. This condition is always present when there are strain gradients, either general or local, since strain is equivalent to grain fragmentation. At other times, however, the grain-size contrast is not present in the original material, but is developed during the heating as the first stage of the germinative process. This is true of the Schaller process and in general of cases where germination is brought about by temperature gradients. Once this condition of grain-size contrast obtains, it is necessary, in order for germination to proceed, that the metal be held at a temperature where the rate of growth of the larger grains is very great as compared with that of the smaller grains among themselves. We may state the condition for germination as follows: *The existence of marked grain-size contrast in a metal at a temperature which permits absorption of the small grains by the larger, but not growth among the smaller grains.*

Germination thus depends upon a sharp difference in the rate of grain growth from point to point in a metal. It seems probable that the important effect of mechanical obstruction on germination is brought about through the establishment of such differences in growth velocity. We may well suppose that a given obstructing material, present in given quantity and mode of distribution, exerts its maximum obstructing effect on grain growth with respect to grains of a certain size. If such is the case, then the presence of obstruction may accentuate the differences in growth velocity already present because of varying grain size, and thereby increase the probability of germination.

Suppose an obstructing material to be present in a metal to an extent of 1 per cent by volume, and to be uniformly distributed in the form of spheres having an average diameter of 0.0001 in. Assuming for the purpose of calculation a simple cubic distribution, the shortest distance between particles is about 0.0004 in., or about four times the diameter of the particles. Now suppose the grains of the metal to be smaller in diameter than the particles. It is obvious that the particles can have no important effect on the growth of such small grains, since so few of the grain boundaries come in contact with them. If the grains are about the same size or slightly larger than the obstructing particles, the interference with grain growth will also be small in the present case, because of the distance apart of the particles. When the average grain diameter is of the same order of magnitude as the distance between obstructing particles, we may expect a rather marked hindrance to growth. Grains of very much larger size should suffer less interference because the relative distortion of their boundaries by the obstructing particles during growth by boundary migration would be less. It is therefore reasonable to assume that the obstruction to grain growth due to discrete particles scattered through a metal is greatest for a certain range of average grain diameter which is approximately equal to the average distance between particles.

According to this hypothesis, the first addition of an obstructing material to a metal would restrict the growth chiefly of the *larger* grains. Since these grains are already endowed with superior power of growth, the presence of such an amount of obstruction would *decrease* the difference in growth velocity between the larger and the smaller grains. The growth of grains of all sizes is opposed to some extent so that the general effect may well be one of grain refinement. Upon further addition of obstruction, a point will be reached where the maximum retarding effect is on those smaller grains upon which the larger germinant grains feed. Conditions are then most favorable for germination. Still further additions of obstructing material may so increase the general resistance to growth that all grains are kept relatively small.

Formation of Nuclei

It has been stated above that in the opinion of the present authors no new crystalline nuclei are formed during recrystallization. There is no evidence that such nuclei are formed except on the appearance of a new crystalline phase, which occurs in the following cases: 1. Solidification from the molten state. 2. Allotropic transformation. 3. Separation from solid solution. 4. Electrodeposition. The first two of these are most important in connection with grain growth.

Growth of the nuclei proceeds by two distinct processes. First, they feed upon the unstable disappearing phase—that is, the molten metal or the unstable allotrope (as the case may be). Secondly, if the temperature and other conditions are suitable, the larger of the new crystalline units grow at the expense of the smaller by the processes of ordinary grain growth. The resulting grain size therefore depends both upon the conditions affecting nuclei formation and upon the conditions affecting grain growth in the new phase.

Both of these factors are illustrated in the allotropic transformation of iron at A_3 (about 900 deg. C.). Suppose a piece of iron at a temperature above A_3 to be cooled very slowly from one end, so that there is a continuous temperature gradient toward the hotter end. As the cooler end passes A_3, grains of the new crystalline phase appear and grow at the expense of the adjacent disappearing high-temperature allotrope. If a sufficiently sharp temperature gradient can be maintained and advanced at a rate slower than the velocity of grain growth, the grains first formed might sweep the entire piece of metal, as in the Schaller process. Slow cooling through A_3 accompanied by temperature

gradients is therefore conducive to the formation of coarse-grained ferrite.

Slow cooling alone produces distinctly larger grains than rapid cooling. This is attributable to grain growth in the ferrite just after cooling through the A_3 temperature. The rigidity of the metal at this temperature is so great that it is possible to form completely the new phase with a grain size much smaller than the equilibrium grain size. Any exposure to temperatures immediately below A_3 therefore results in normal grain growth.

Other conditions being the same, the grain size of the new allotrope formed on heating or cooling through A_3 is roughly proportional to the grain size of the modification from which it was formed. This principle, which has been called "grain-size inheritance," is believed to depend on the fact that the nuclei of the new phase form most readily in the old grain boundaries.[9]

The fact that grain growth is seldom if ever observed on reheating single-phase cast metals is perhaps responsible for a rather general belief that there is no growth at the expense of *solid* grains during the solidification of metals. This belief leads to the conclusion that all of the crystalline nuclei formed persist, so that the number of grains in the solid metal is equal to the total number of nuclei formed during solidification. The grain size of a cast metal is then held to be a direct consequence of the laws of nuclei formation. This theory of the solidification of metals has been particularly developed by Tammann.[10]

The present authors have indicated above their opinion that normal grain growth involving the absorption of solid grains occurs during and perhaps shortly after solidification. On this basis, the number of grains left on cooling is very much less than the number of nuclei formed. There is considerable evidence that actual solidification is preceded by the formation in the liquid of groups of atoms which are essentially crystalline nuclei and yet obviously some of these groups are absorbed by others during solidification.

Germination in a solidifying alloy may be explained in very much the same way as germination in a solid metal. In the case cited, the first addition of obstructing material caused general interference with growth, but with a maximum effect on the larger potentially germinant grains. A further addition produced germinant conditions by exerting a maximum obstructing effect on the smaller grains, thereby preventing them from coalescing into large grains of greater resistance to absorption. Finally, the obstruction became so great that no grains could attain abnormally large size.

The Distortion Theory of Grain Growth

Within recent years there has been developed, largely by Czochralski,[11] an interesting theory that grain growth is caused by varying distortion of the crystal lattice. It is known that when a metal is cold-worked, internal stresses are left which must necessarily involve elastic distortion of the grains or grain fragments. It is also quite certain that the amount of relative distortion varies from grain to grain. The grains which are distorted the least are most stable and are, from the thermodynamic point of view, in a position to grow at the expense of the more severely distorted crystalline material. The distortion theory postulates that when such growth takes place, the atoms added to a grain arrange themselves in a lattice having exactly the same degree of distortion as that of the growing grain. Grain growth then involves a progressive decrease in the elastic energy of the metal due to lattice distortion. At any given temperature a state of metastable equilibrium is reached.

On heating to higher temperatures, the decreased inertia enables more growth to take place, always with a differential distortion as the cause.

This theory accounts very nicely for the absence of growth in unstrained castings, and fits in well with many of the grain growth phenomena. It depends, however, upon an assumption (which appears to the present authors so improbable as to require quite definite proof) that lattice distortion and hence internal stress exists in metals which have been fully annealed. The effect of heat upon internal stresses has been fully investigated in connection with the season cracking of brass, and it has been found that these stresses are reduced to a vanishing point by annealing *below* the temperature of recrystallization. It does not therefore seem likely that at temperatures several hundred degrees higher any appreciable distortion can exist. The surface energy due to small grains is present at all temperatures, and can be reduced only by grain growth. On the other hand, cast metals can be obtained in a condition of internal stress nearly equal to the elastic limit and involving practically the maximum possible lattice distortion in some of the grains, which distortion can be removed on heating without causing any grain growth. Such considerations lead to the conclusion that surface energy is the principal cause of grain growth.

General Propositions

1. Crystalline nuclei are formed only on the appearance of a new crystalline phase.
2. Crystalline nuclei may grow by the absorption not only of the disappearing phase but also of each other, so that the final number of grains may be less than the total number of nuclei formed.
3. Grain growth results from the tendency of metals to assume the form of greatest possible physical stability.
4. The principal conditions conducive to grain growth are small grain size and grain-size contrast.
5. Grain growth is opposed by mechanical obstruction and by inertia due to low temperature.
6. A condition of metastability as regards grain growth must be recognized, in which, while the metal is not in the most stable form, the forces tending to cause grain growth are insufficient to overcome the opposition to growth. As the temperature rises, this condition of apparent equilibrium approaches that of maximum stability.
7. Recrystallization is essentially grain growth on a submicroscopic scale.
8. Germination consists in the preferential growth of certain grains favored by their large size. The necessary condition is the existence of grain-size contrast and suitable temperature such that the larger grains can grow at a considerably more rapid rate than the smaller grains.
9. There is a critical amount of mechanical obstruction which favors the establishment of this necessary difference in growth velocity and hence germination.

Lead and Zinc Tailings May Be Used as Fertilizer

Tailings from the lead and zinc mines of southwestern Wisconsin may be used by farmers in that vicinity for fertilizer. After experiments with this byproduct at the Wisconsin University it is claimed that it may be a satisfactory source of lime for correcting soil acidity. The experiments further indicated that there are no dangers from the possible poisonous effect of the lead and zinc or the development of sulphuric acid through the oxidation of the sulphide. Quantities as large as 4 or 5 tons to the acre have been used without injurious results and with marked benefit to the clover and alfalfa. The better grade tailings, if dried and ground, would be satisfactory for shipment.

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[9] "Grain Size Inheritance in Iron and Carbon Steel," Zay Jeffries, *Trans.*, A.I.M.E., vol. 58, pp. 669-695 (1918).

[10] "Text Book of Metallography, in German, 1914.

[11] "International Zeit. für Metallographie," vol. 6, pp. 289-296 (1914). Also Masing, "Zeit. für Metallkunde," vol. 12, p. 457 (1920).

High Temperatures in Industrial Processes

Use of Various Liquids and of Superheated Steam for Transmitting the Heat Required in the Preparation and Processing of Chemicals and Allied Materials—Development of Direct-Fired Tubular Heaters for Use in the Process Industries

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ONE of the difficult problems confronting the combustion engineer is to obtain the high temperatures often required in modern manufacturing processes in which overheating is likely to result in a loss of products. The solution of such a problem necessitates a thorough working knowledge of the many methods which may be employed as well as the ability to select from these the one which is best adapted to the peculiar characteristics of the particular process. As a matter of fact, the difficulty lies as much in the choice of the most efficient method as it does in its design or application. For example, a chemical manufacturer will commit a serious economic error if he selects, out of the several different methods which are available, one with high operating or maintenance charges. Any decision should be based on a thorough study of the relative advantages and limitations of each of the possible methods.

For the purpose of this article, high temperatures will be considered as those which are higher than can be obtained by the use of steam under moderate pressure. The methods to be considered will be limited to applications in which the delicate nature of the product precludes the use of a direct-fired kettle. By using steam at 150 lb. pressure in a closed coil or jacket, a temperature of approximately 350 deg. F. could be obtained in the product. Where temperatures higher than this are necessary in a plant having only ordinary boiler equipment and cast-iron fittings, a different sort of heating medium is required. It will be useful to consider the various methods available for this purpose, discussing in each case the characteristics which might either recommend or preclude the practicability of each for use in a particular case.

Transmission of Heat by a Liquid

The transmission of heat by a liquid consists in circulating a high-boiling liquid as a medium for conveying the heat from a direct-fired heater to the heating tank. The liquid is kept in continuous circulation by a pump between the heater and a coil placed in a tank containing the material to be heated. As the liquid travels through the tubes of the heater its temperature is raised and its total heat content is increased proportionately. Subsequently in passing through the coil or jacket of the heating tank the heat is transferred from the circulating liquid to the material being heated. Thus the liquid in the system is kept in continuous circulation and is always maintained at a higher temperature than the material to be heated.

A mineral-oil distillate of high flash point is the liquid most commonly used. The oil gives satisfactory results, as it is easy to pump, has a specific heat of about 0.5 and need not be kept under any pressure except that required to give the necessary pumping head and to exclude air. If a liquid of a lower boiling point is employed, a considerable pressure has to be carried on the system in order to keep the liquid from vaporizing. It is possible to obtain temperatures as high as 550 or 600 deg. F. by employing this method with oils now available. The limiting factor as far as high temperatures are concerned is the temperature at which the oil will crack. Overheating and possible burning of the tubes of the heater can often be attributed to the carbon deposited during the cracking or burning of the oil.

A high efficiency can be obtained by the circulation of a hot oil, due to the fact that the same oil is reheated continuously, and that no heat is lost by either rejecting the heated oil from the system or reheating make-up material. The two factors which limit the efficiency of the system are the economy developed in the oil heater and the radiation losses suffered by the oil in traveling from the heater to the heating tank. It is obvious that the oil heater should be located as close as possible to the heating tank and that the pipe lines carrying the oil to and from the tank should be well insulated. The radiation losses at fairly high temperatures in the tank are very large. Whereas it might not pay to go to the expense of lagging a tank which contains the material at 200 deg. F., it would be entirely a different matter if the temperatures were 400 deg. F. or above. Other conditions remaining constant, doubling the temperature difference between the material and the outside air will double the heat lost by radiation.

Design and Operation of Oil Heater

Having reduced the radiation losses to a minimum, the residual overall efficiency of the system depends entirely upon the design and operation of the oil heater. It should be remembered in this regard that the flue gas temperatures from the heater cannot be lower than the cool oil returned from the heating tank. Let us assume, for example, that the heater is designed along counter-current principles of flow with the coolest oil meeting the coolest gases. In this way the flue gas temperatures are reduced to the lowest possible point. But if the oil is being circulated at a high temperature with a small drop in going through the heating coil, it will necessarily follow that the gases will leave the heater at a fairly high temperature. A definite problem will serve to bring out this point. In certain acid-treating processes it is necessary to obtain temperatures of 400 deg. F. For this purpose the circulating oil passing through the heater will be raised in temperature to 475 deg. F. In passing through the heating coil and back to the heater inlet the oil loses 50 deg. F., which means that the oil at 425 deg. F. will meet the waste gases just before they are discharged. In order to make the surface at this end of the heater effective,

the gases must leave at a temperature slightly above the oil which they are to heat. For this reason the gases could probably not be cooled below 500 deg. F.

Assuming that complete combustion is being obtained in the heater, an efficiency of 70 per cent could be maintained even with the waste gases at 500 deg. F. To get the ultimate efficiency of the actual transfer of heat from the fuel to the product, deduction must be made for radiation losses. If all parts of the equipment are well insulated, this loss in the average case should not exceed 10 per cent. On this basis, therefore, a high-temperature effect could be obtained at about 63 per cent efficiency, and even in unfavorable cases this should not fall below 50 per cent.

As has already been stated, the temperature which can be developed with this method depends upon the temperature at which the oil can be circulated without danger of cracking. Even where the oil is to be circulated at temperatures which are well below those at which cracking might be expected, extreme care must be taken to avoid local overheating. Improper circulation or faulty combustion in the furnace might cause overheating and cracking of a portion of the oil in some tube section. The deposit of carbon resulting prevents transfer of heat through the tube to the oil passing on the inside, resulting in overheating and possible burnouts.

The danger of leaks in the oil heater and consequent fire hazard have been the subject of some objections to this system. However, if all joints of the heater are located outside the path of the hot gases, there is no danger of an oil leakage causing a fire and thus this danger is eliminated. Provision should also be made that a leak in a tube itself will not pour oil down into the combustion chamber.

The use of a circulating oil for heating in this way has been in very common use for the last 10 or 12 years. The close control possible has brought it into great demand in the many processes in which temperature fluctuations would be ruinous to satisfactory results. A list of products which have been treated in this way would require more space than is available in this paper, but among them might be mentioned some of the more important, such as paints, food products, acids, soaps, asphalts, vegetable oils and various chemical products.

Use of Superheated Steam

Superheated steam may be successfully employed for high-temperature heating in many different ways. All of these methods, however, may be classified under two heads according to whether the steam is actually mixed with the material to be heated or is employed indirectly in coils or jackets.

The direct use involving the injection of steam directly into the mass of the material to be heated is the more simple of the two methods and its advantages are more apparent. Fundamentally superheating steam is not only raising its temperature but is also increasing its total heat content. Just how much certain degrees of superheating add to the heat in a pound of saturated steam at 100 lb. pressure is shown in the following portion of the steam tables:

Degree of Superheat		Total Heat per lb. Above 32 deg. F. in B.t.u.	Percentage Increase in Heat Content Over Sat. Steam
Saturated	0	1,189	0
	100	1,243	5
	200	1,293	9
	300	1,342	13

It is therefore apparent that if it is desired to heat up a specified weight of liquid to a certain temperature it can be done with a smaller weight of steam by superheating. The figures given are based upon a comparison between dry saturated steam and steam with varying degrees of superheat. In actual practice the comparison is even more favorable to superheating, because the saturated steam suffers considerable heat loss, producing condensation. This appears as moisture in the steam, the amount varying with conditions such as the distance the steam must be piped to the heating tank. Superheating eliminates this moisture and thus makes an additional saving.

An idea of how superheating cuts down radiation losses may be gained from the following record of test on a long pipe line. It will be noticed that besides eliminating moisture superheating also reduces the drop in pressure.

Test Taken on 4-In. Line 500-Ft. Long, and Well Covered

Initial boiler pressure, lb.	120
Drop in pressure in line, lb.	3
Superheat at superheater, deg. F.	140
Superheat at end of line, deg. F.	90
Loss of superheat, deg. F.	50

In the heating of many substances the required temperatures cannot be obtained with saturated steam at ordinary pressures and often these pressures cannot be raised because of the condition of the boiler and steam piping. In instances where such conditions exist the steam has been superheated before being blown into the material and the necessary temperature increase obtained. The heating of vegetable oils for purposes of deodorization is an excellent example of this application. In the deodorization of these oils certain odoriferous constituents are volatilized. The temperatures at which these substances can be vaporized is in many cases above that of medium-pressure saturated steam. As steam can be superheated to a high final temperature regardless of its pressure, the oils can easily be raised to the desired point by the installation of a superheater. Also in many processes the agitation obtained by blowing superheated steam into the mixture is an important consideration.

Use in Closed Coils or Jackets

The successful use of superheated steam for heating in coils or jackets is by no means a simple problem, although in some cases it can be utilized with good economy and satisfactory results. It should be definitely noted, however, that it cannot be used in the same way as saturated steam. Often attempts are made to obtain high temperatures in a material in a kettle by merely substituting superheated steam for saturated steam in a closed coil. The results obtained are practically always disappointing.

Let us assume that we have a kettle equipped with a heating coil which has a trap on the outlet. Superheated steam is allowed to fill the coil. Before any of this steam can condense, the superheat must be given up. Consequently part of the coil is filled with saturated steam and no more superheated steam can enter until this is condensed. The temperature effect produced by this portion of the coil is therefore that of the saturated steam. The part of the coil nearest the inlet is filled with superheated steam, but even this heating surface does not afford a higher temperature. As shown in the section of the steam tables previously cited, superheating a pound of steam 100 deg. F. adds

5 per cent to the total heat content. On the other hand, it increases its volume 17 per cent.

The part of the coil filled with superheated steam therefore contains 17 per cent less steam than it would if the steam were saturated. As this superheated steam has only 5 per cent more heat per pound, it is obvious that there would be less heat units present than in the case of saturated steam. A temperature effect is after all dependent upon the transfer of the requisite number of heat units to produce the necessary increase; therefore the cutting down of the total heat content of a part of the coil will not produce any higher temperature. In addition to the fact that there are less heat units present, these heat units are given off but slowly because superheated steam parts with its heat so reluctantly. It therefore follows that superheated steam cannot usually be employed in a closed jacket or coil to obtain a higher temperature than saturated steam would have afforded.

If superheated steam is to be used to obtain high temperatures, then it must be allowed to circulate at a high rate through the coil or jacket and must leave the heating surface usually with some degree of superheat remaining in it. Thus it would be possible to heat a material up to 700 or 800 deg. F. by superheating steam to 1,000 deg. F. and allowing it to blow through a coil in a kettle. In this case, however, during the latter part of the operation the steam would have to leave the coil at temperatures above 800 deg. The practicability of this method of heating depends upon whether the heat remaining in the steam when it leaves the coil can be utilized. In some plants it has been found possible to connect up the coils of several kettles in one continuous series, staging the operation of the kettles down in temperature so that the steam can leave the last one at a fairly low temperature. The superheated steam of the highest temperature enters the high-temperature kettle and travels on to where its lower temperatures still provide a heat head. Usually this steam has no remaining superheat upon leaving the last coil and is then used in feed water heating or in some operation where the saturated steam can be condensed and the latent heat recovered.

Use With Series of Coils or a Series Superheater

The method of passing superheated steam through several coils in series gives the steam a long travel through small pipes and usually exhausts practically all the pressure in the steam. In certain cases the amount of material to be raised to a high temperature is so small that only a small coil is required. Superheated steam can be passed through such a coil with a small drop in pressure and the high-pressure saturated steam upon leaving the coil can be fed to engines or pumps. In this application the saturated steam has acted merely as a conveyor for the high-temperature effect of superheat to the process. As far as the economy of the saturated steam on the engine equipment is concerned nothing has been lost except a few pounds pressure. Moreover, if the material to be heated required a high temperature, the steam would leave the coil with considerable superheat remaining and the economy thereby produced on the engine would more than make up for the slightly lower pressure.

A series superheater has also been employed to resuperheat steam several times, alternately heating it and delivering the high-temperature heat units to a process. As this method involves using the same saturated steam to get a high-temperature effect by superheating it five or six times, only a small weight of steam is required and the economy obtained is very high.

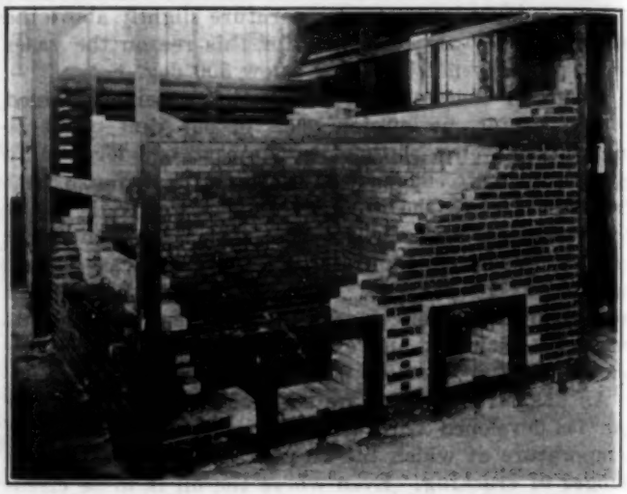

FIG. 1—DIRECT-FIRED TUBULAR HEATER FOR VEGETABLE OILS (UNDER CONSTRUCTION)

View shows armored heating surface placed behind protecting bridge wall.

In one plant where this system is employed they have been able to demonstrate an efficiency of 75 per cent. The design and installation of such a system are complicated and are usually intrusted to experts in the use of superheated steam.

Direct Heating of Materials

While it will not be attempted in this paper to discuss all the heating problems which can be solved successfully in a direct-fired kettle, it still seems worth while to point out what can be accomplished in obtaining high-temperature effects in a delicate material by means of a heater of tubular construction. At present many materials are being heated in this way which could not be handled with uniformly good results in an ordinary kettle or cylindrical still.

The obvious objection to the kettle or cylindrical form of heater is the difficulty of heating a material with any degree of uniformity. In these vessels only a small part of the material is in contact with the heating surface at the bottom where the vessel is exposed to the furnace. The result is that this material becomes very much overheated while the greater mass in the cooler parts of the vessel are insufficiently heated. Even though artificial means of establishing a circulation are resorted to, the movement set up is usually poor and cannot be counted on to maintain a uniform temperature in the product. This objection is sufficient to prevent the use of this method of direct heating in the case of many processes.

Development of Special Tubular Heaters

On the other hand, a properly designed tubular heater will often eliminate this disadvantage and make it possible to solve in this way many problems in which a slight overheating would be disastrous to the material being heated. If the heating surface consists of a series of pipes or tubes through which the material is pumped continuously and if the heat from the furnace is applied so as to avoid concentration at any point, the material will be heated gradually and evenly from

the time it enters the heater until it reaches the outlet. Moreover, the temperature in the material will gradually increase through the heater and can be brought to the proper maximum at the outlet by varying the rate of circulation and the firing.

Although it is admitted that a careful study of furnace construction and methods of applying heat generated in a furnace to a tubular heating surface should give uniform heating, the successful development of such a heater has presented many problems. Complete combustion is usually accompanied by high temperatures in the combustion chamber. The radiant heat thus evolved has a constant tendency to overheat the tubular heating surface unless some steps are taken to protect the tubes from this powerful source of heat. The first heaters of this type were built with the tubes located directly above or in the rear of the combustion chamber. With this design, however, the destructive effect of radiant heat in many cases led to frequent burning out of the hottest tubes. In other words, the radiant heat would be poured into these tubes faster than the heat-absorbing material circulating in the inside could absorb it. As radiant heat always travels in straight lines, the next step in the development of these heaters was to screen the tubular heating surface from the direct rays of heat. This was accomplished by placing the heating surface behind a bridge wall which separated it from the fire. The adoption of this design did much to eliminate the troublesome effect of radiant heat. Even so, when a heater of this design was fired hard, the heat from the combustion chambers would eventually become intense enough to raise the brick roof to a red heat. This incandescent brick in turn would reflect the radiant heat down on to the upper rows of heater tubes and would, under severe conditions, still cause local overheating and tube failures. The final step in the development of these heaters was the installation of heating surface of special construction opposite and above the main section of heating surface. Such a heater is shown in Fig. 2. The front part of the tubes directly over the furnace is screened from radiant heat by special tile. The rear part of the tubes directly over the heating surface behind the bridge wall has no tile protection, but the steel tubes are covered with a special solid cast-iron casing only a small portion of the surface of which is exposed to radiant heat. As these two opposing heating surfaces are both cooled by the liquid passing through the tube and hence are at approximately the same temperature, there can be no exchange of heat or radiation.

The tubes back of the bridge wall absorb the heat generated in the furnace almost entirely by convection and therefore at a much lower rate than by radiation. This feature tends to prevent overheating in any of the tubes and therefore makes it possible to heat the most sensitive materials without danger of spoiled products. This construction also furnishes a durable roof and improves the heater efficiency by reducing the radiation losses from the roof.

Direct Heating of Vegetable and Mineral Oils

The heating of vegetable oils for deodorization purposes is one of the difficult problems which has been solved in a tubular heater. In this process a uniform rise in temperature is essential and for many years it was believed that superheated steam offered the only satisfactory method of heating with the necessary close control. The oil must be raised to a certain temperature to obtain proper results and if any of the oil is

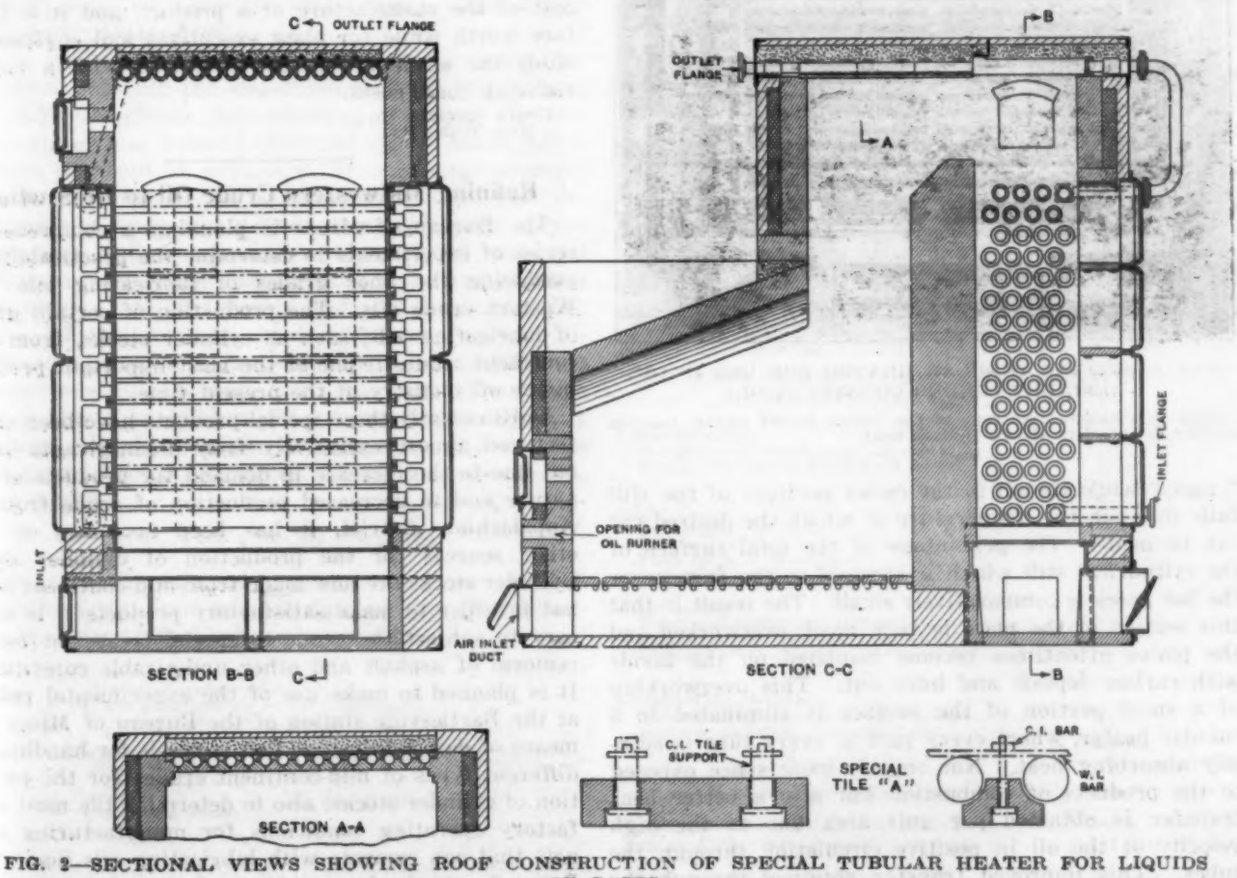

FIG. 2—SECTIONAL VIEWS SHOWING ROOF CONSTRUCTION OF SPECIAL TUBULAR HEATER FOR LIQUIDS OR GASES

unevenly heated and has a temperature below or above this predetermined limit a complete refining is not accomplished—in fact, the whole batch may be ruined. Many vegetable oil refineries are now using tubular heaters with excellent results as far as the quality of the product is concerned and greater economy than could be obtained with other methods.

As an average it may be stated that the efficiency of one of these special heaters would be about 60 per cent, although an efficiency of 67½ per cent has actually been demonstrated in some installations. The average efficiency of heating with steam in the case of vegetable oils probably does not exceed 20 per cent. The saving in time required to heat a given batch of oil through a specified temperature rise is also an important advantage. In one of these heaters it is possible to treat in 1 hour a weight of oil which would require from 2 to 4 hours in a steam still.

In the mineral oil refineries the tubular heaters have also made considerable progress in the last few years. In the cylindrical stills commonly used in refineries of this country many troubles have been encountered due to improper circulation and faulty combustion. Oil is admittedly a poor conductor of heat. As a result the oil in contact with the bottom of the tank is likely to

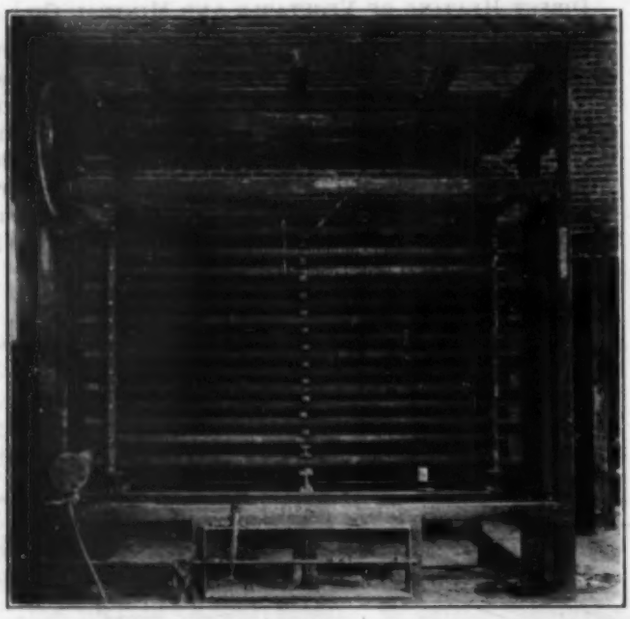

FIG. 3—SPECIAL TUBULAR HEATER FOR USE IN OIL REFINERY (UNDER CONSTRUCTION)

This view taken from rear of the heater shows special heating surface designed to absorb radiant heat.

"crack," while the oil in the cooler portions of the still fails to reach the temperature at which the desired cut can be made. The percentage of the total surface of the cylindrical still which is exposed to the furnace or the hot gases is comparatively small. The result is that this section of the plate is very much overworked and the plates oftentimes become insulated on the inside with carbon deposit and burn out. This overworking of a small portion of the surface is eliminated in a tubular heater, where every part of every tube is actually absorbing heat. Not only is more space exposed to the products of combustion but also a better heat transfer is obtained per unit area due to the high velocity of the oil in positive circulation through the tubes. This improved transfer obtained through the metal wall acts to prevent local overheating such as is encountered in the bottom plates of a tank still.

Almost any liquid which can be pumped can be handled in a tubular heater in this way. Besides mineral and vegetable oils, several heaters are now operating in roofing plants heating up the asphalt coating. Many gases have also been successfully heated to a high temperature in heaters of this same general type. In one case a highly flammable gas is being heated to a temperature above 1,000 deg. F. under a pressure of 1,500 lb. per sq.in. In all high-temperature heating problems it is well worth while to ascertain whether the material under consideration cannot be treated directly. From a consideration of the many materials handled in this way it is evident that in many cases direct heating can be utilized with much better economy than is possible with any indirect system.

Waste Heat

Where waste gases at fairly high temperatures are available, heat interchange apparatus enables effective use to be made of this waste heat in obtaining high temperatures in processes. Ordinarily waste gases are at too low temperatures to be of use for this purpose, but in the case of some furnaces or kilns the gases are available at temperatures of 1,000 or 1,200 deg. F. In this case they can be used with great economy, and advantage should be taken of this source of heat available with no additional fuel costs. Just as in the cement plants, waste-heat boilers are installed to utilize the gases from the kilns, so in chemical and other industrial plants hot waste gases can and are being used as the means of obtaining high temperatures in a process. In many of these industries the cost of obtaining high temperatures constitutes a large proportion of the total cost of the manufacture of a product, and it is therefore worth while for plant executives and engineers to study the efficiency of such processes with a view to reducing these costs.

Power Specialty Co.,
New York City.

Refining Midwestern Crude Oil to Be Studied

The Bureau of Mines is planning a comprehensive series of experiments to determine the practicability of producing the finer grades of lubricating oils from Western crude oils. The production of certain grades of lubricating oils, such as cylinder stocks, from mid-continent crudes is one of the most important problems in the oil industry at the present time.

Until recently these special products have been manufactured almost exclusively from Pennsylvania crude, but due to the increase in demand for products of this nature and to decreased production of crude from the Appalachian district, it has been necessary to seek other sources for the production of cylinder stocks. Cylinder stocks are now made from mid-continent crude, but in order to make satisfactory products it is necessary to subject the crude to special treatment for the removal of asphalt and other undesirable constituents. It is planned to make use of the experimental refinery at the Bartlesville station of the Bureau of Mines as a means of determining the best methods for handling the different types of mid-continent crudes for the production of cylinder stocks, also to determine the most satisfactory operating conditions for manufacturing products that can compete with lubricating oils made from Pennsylvania crude.

The German and American Synthetic-Ammonia Plants*—V

Costs of Construction and of Ammonia Production in the Plants at Oppau, Germany, and Sheffield, Ala., Are Compared and the Synthetic-Ammonia Problem Is Considered From the Viewpoints of the Chemist, Engineer, Operator and Executive

By R. S. TOUR

THE entire construction cost chargeable to the Oppau plant will total perhaps 250,000,000 marks. If the original pilot plant, the coke plant, the ammonia-utilization plants—i.e., ammonium sulphate, and nitric acid—be neglected and corresponding reductions made in the general facilities investment, the cost chargeable to the manufacture of ammonia alone is about one-half the entire cost, or some 125,000,000 marks. Of this about one-third is chargeable to buildings and construction, and two-thirds to equipment and machinery. The former includes buildings, foundations, roads, trackage, and all general construction; the latter covers special equipment or machinery and includes its installation cost. This is an estimate of actual pre-war (1914) cost and would mean an investment of about $270 per annual short ton of ammonia capacity, or $100,000 per daily ton. This cost applied only for the conditions existing in Germany at the time considered. In 1916, the construction costs at Merseburg showed an increase of more than 50 per cent over the Oppau figure in view of the rising labor and material charge. The 1918 estimate, based on the construction costs for the last one-fourth capacity of the Merseburg plant, had increased 150 per cent over the 1914 figure. (1914—$270; 1916—$400; 1918—$700.)

It is difficult to arrive at the labor necessary for operation. During the war there were at Oppau more than 6,000 workmen, not counting prisoners of war. This number was reduced after the war to about 5,000, directed by about 50 engineers through many superintendents and foremen. These figures include all departments of ammonia utilization, as well as construction, repair and maintenance. About 3,500 men and 35 engineers are chargeable normally to the manufacture of ammonia, including repair and maintenance of the plant. Of this number about 2,500 are required directly on operation. The labor charge of 2,500 men represents about 66 man hours per ton. The wages paid at Oppau in 1914 might average about 0.6 mark per hour. By 1918, wages had gone up in about the same proportion as the construction costs above—i.e., to 1.5 marks.

Fuel and Upkeep Charges

The only raw material necessary at Oppau is fuel. Estimates based upon reliable data indicate the following quantities of fuel per ton ammonia:

a. For water gas generators (Hydrogen production)	2 tons coke
b. For lean gas generators (Nitrogen production)	
c. For gas producers (Power and steam)	1 ton coal
d. For boilers (Steam and power)	2 tons lignite

The power and steam consumption is all included under (c) and (d). The power developed as such seems to be of the order of 3,000 kw.-hr. per ton of ammonia. The steam developed by gas engine exhaust or by boilers and consumed directly (not in steam engines) is perhaps 8 tons per ton of ammonia.

For the maintenance and repair charges (including materials and labor) we may assume 2 per cent per annum for buildings and construction and 8 per cent for equipment and machinery, which averages 6 per cent for the ammonia installation. For depreciation and amortization, we may allow 4 per cent for buildings and 7 per cent for equipment, which also averages 6 per cent for the installation. A charge for development and obsolescence is properly made on this type of plant and this has been allowed at 6 per cent on equipment and machinery only. As the process becomes more standardized and better developed this charge will decrease till it may be absorbed as depreciation and amortization, then taken at 10 per cent. These differentiations are delicate ones, since certain repair charges may be classed as depreciation while certain obsolesence charges may properly be classed with amortization. The total plant-upkeep charge per annum can be conservatively taken at 16 per cent of the investment for this type of installation.

	Buildings and Construction, Per Cent	Equipment and Machinery, per Cent	Average for Plant, per Cent
Maintenance and repair	2	8	6
Depreciation and amortization	4	7	6
Development and obsolescence	0	6	4
Total plant upkeep	6	21	16

In addition there are such fixed charges as interest, insurance, and taxes, which we may sum up at 9 per cent. The total for plant upkeep and fixed charges

PLANT PRODUCTION COST PER TON OF AMMONIA AT OPPAU, GERMANY, IN 1914

	Marks	Dollars
Labor Operating:		
35 engineers at 10,000 marks per annum	3.2	
66 man-hours per ton at 0.6 mark per hr	39.6	
	42.8	($10.27)
Fuel:		
2 tons coke at 20 marks	40	
1 ton coal at 15 marks	15	
2 tons lignite at 10 marks	20	
	75	($18.00)
Plant Upkeep:		
Repair and maintenance at 6 per cent	68.2	
Depreciation and amortization at 6 per cent	68.2	
Development and obsolescence at 4 per cent	45.5	
	181.9	($43.66)
General Works Expense:		
Unclassified expenses, 10 per cent of above	30	
Incidental materials, 5 per cent of above	15	
	45	($10.80)
Fixed Charges:		
Interest, insurance, taxes (at 9 per cent)	102.3	($24.55)
Total production cost per short ton of ammonia	447.0	$107.28
Total production cost per pound of ammonia	0.2235	0.05364

*For Parts I-IV see CHEMICAL & METALLURGICAL ENGINEERING, vol. 26, Nos. 6, 7, 8 and 9, pp. 245, 307, 359 and 411.

(25 per cent) represents over half the production cost of ammonia.

In the accompanying table is given an estimate for the cost of ammonia per ton as produced at Oppau in the form of aqua in 1914-1915, at the time the plant was developed. The cost in German marks for 1918, based on Merseburg experience and prices then existing, may be taken at about 2½ times the 1914 figure. The 1918 figure may be indicative of the present-day cost in Germany, although in view of the unsettled conditions and the prevailing rates of exchange any figures given for post-war conditions are to a large extent meaningless.

Construction Costs for the American Plant

The actual construction cost of the entire plant at Sheffield as built under emergency conditions was about $13,000,000. Thus included the nitric-acid and ammonium-nitrate plants, as well as the village for housing the employees. Of the total amount, about $7,000,000 is chargeable to synthetic-ammonia manufacture if all else be neglected and necessary deductions be made in general facilities. The plant was in many ways not completed and an additional $1,000,000 must be allowed for this purpose. This additional allowance does not consider the changes or improvements necessary for successful operation, but is to cover the incomplete installation of Unit No. 3 at the plant, the omission of properly equipped repair shops, and the future requirement of a laboratory and office building. The total of $8,000,000 represents costs under emergency conditions and may be reduced by 25 per cent for an estimate of normal construction costs at the close of the war. Based on the rated capacity of 10,000 tons per annum, the normal investment per annual ton of ammonia would thus be about $600, which at first sight compares favorably with the later construction costs of the German plants. However, in making any comparison, the following points must be kept in mind: (1) The rated capacity of the Sheffield plant may not have been its production capacity. (2) The investment in Germany included gas producers, gas engines, etc., which were necessary there to reduce the power charges and which in the United States are in general not necessary. For purposes of estimating costs for present-day construction in the United States, we can not allow less than $500 per annual ton of ammonia for plants of capacities comparable with that at Sheffield.

Based on a $500 investment per annual ton of ammonia, plant upkeep and fixed charges will represent a cost of about $125 per ton of product. The additional cost for labor, materials (fuel, power, steam, water) and other direct operating expenses will be of a like magnitude. No attempt is made here to develop these latter costs since they would depend upon the specific conditions existing at any particular plant. The total plant production cost, whether it be $250 or $300 per ton ammonia, of course includes no distribution, sales, or main office expense. It is evident from this superficial survey of costs that improvements of efficiencies at different steps of the process, with corresponding slight reductions in fuel, labor or power consumption, will not in any large proportion decrease the cost of the product. Any great saving must be accomplished by the use of the byproduct, carbon dioxide, from the process or by a reduction in the investment.

The only byproduct from the process is carbon dioxide, which is available to the extent of 40,000 to 45,000 cu.ft. per ton of ammonia. Its utilization requires the installation and operation of some additional process using the carbon dioxide and preferably a process using the ammonia as well. This calls to mind, first, the ammonia-soda process, turning out as final products ammonium chloride and soda ash. This combination of processes is in every way logical, but not as simple as it might appear. Interdependence of the two processes will make operation increasingly more difficult. Although the byproduct, carbon dioxide, would be of direct use in the ammonia-soda process, still lime would remain necessary for causticizing. The marketability and desirability of the ammonium chloride, as well as its preparation from the liquors, are also important factors. The complicating features just mentioned can be overcome in time should necessity require. A much less intricate, though less valuable, utilization of carbon dioxide is that for the double decomposition of gypsum in the presence of ammonia, yielding ammonium sulphate as the product and discarding the calcium carbonate. The German plants are using both of the above combinations, finding advantages in each. They have also experimented with the direct combination of ammonia and carbon dioxide for conversion to urea as the final product. The latter would be a very desirable solution of the entire problem of ammonia and carbon-dioxide utilization.

Some reduction in investment per unit production may be obtained by plants of very large capacities, but as long as these plants consist of multiple items of apparatus, each of comparatively small capacity, such reduction of investment can be only of a secondary order. Any large reduction in the investment must presuppose fundamental modifications of the process, as installed either in Germany or the United States. Such changes must be basic in character and represent definite reductions in the quantity or in the cost of equipment necessary for operation.

Concluding Remarks

The German process and combination of processes reached their present state of development with the financial aid of the government and under military pressure. As has been stated previously, a pilot plant had been built and preliminary experimentation completed by 1914, before the final construction and operation of the large Oppau plant to supply Germany's war needs. It is a question whether private capital would have of itself invested such large sums in the Oppau and Merseburg plants in normal times or without governmental aid. It is a further question as to whether post-war conditions are as favorable for private capital as were the pre-war conditions. We know, however, that since the plants have been built and operated successfully during the war to produce large quantities of ammonia, those plants must continue to operate and furnish ammonia for home consumption and export. The cost figures from those plants may mean but little, for a great part of their construction cost and development has been written off as a war charge.

The synthetic-ammonia industry in this country is at present in a status similar to that in Germany at the time the pilot plant at Oppau was being developed, although there is not here the enormous pressure and stimulus for development that the government put behind the German installation. It would be obviously unfair to compare the experimental plant at Sheffield

with anything but the original pilot plant in Germany. The main Oppau plant was the final development from the experimental stages through which any new and complex process must pass. Unless the Germans should take up actual construction in this country and make available their store of experience and knowledge, the industry in this country must develop its own industrial installation.

The Problem From Various Viewpoints

It is said that the industrial development of the direct synthetic-ammonia process is the greatest of modern chemical engineering problems. The true aspects of the problem, however, are somewhat beclouded by the difference in viewpoint of those following or aiding in its developments. The research chemist realizes quite rightly that the chemical problems involved are of the simplest nature except for the final step of catalysis of hydrogen and nitrogen to synthesize ammonia. He, therefore, feels that if he can develop an active and satisfactory catalytic material, the entire problem is in general solved and it remains but for the engineer to design and erect the plant. The designing engineer, on the other hand, feels that the development of a catalyst is a specific laboratory problem with which the research chemist is properly equipped to cope, but that the design of dependable equipment to operate at high pressures with temperatures at times approaching a red heat, and with gases or liquids sometimes corrosive on the materials of construction, is the really serious obstacle to success. He is appalled at the lack of data and precedents at hand for his work and is certain that if he succeeds all else is relatively simple and it only remains to erect and operate the plant. The operating chemical engineer to some extent appreciates both the above viewpoints, since he realizes to what extent his success depends on the success of both the chemist and the engineer, but he further feels that the determination and proper control of the many complicated and interdependent operating variables and steps of the process are in the last analysis the real basis of success. The industrial interests in control of commercial development have still another viewpoint. They appreciate only to a small extent the problem of the research chemist, the designing engineer, or the operating chemical engineer, but rightly feel that the success of the above men is for them a failure if the resulting investment, fixed charges or operating expenses make the cost of the product prohibitive.

Successful development of the synthetic-ammonia process can be attained only by a full appreciation of all the above viewpoints properly weighed against one another and by the most conscientious co-operation among the chemists, engineers, operators and executives. A new plant availing itself of the experience gained in operation at Sheffield, and of information obtained since then, should show very great improvement over the Sheffield plant, and there is no reason why the process could not finally be developed successfully in this and other countries as well as in Germany, if the demand for the product is sufficient to justify the investment.

Tax Returns of Precious Metal Companies

Companies engaged in the smelting and refining of precious metals in 1919 paid a total tax in that year of $6,615,353. The number of companies making returns was 567. Of this number 505 had net incomes totaling $26,285,275.

The Possibilities for Commercial Development of Muscle Shoals*

By Richard C. Tolman
Director, Fixed Nitrogen Research Laboratory

THE Muscle Shoals plant is designed to produce 220,000 tons of cyanamide per annum, which is later transformed into ammonium nitrate, amounting to 110,000 tons, as the final product of the plant. The raw materials which are used in the process are air, limestone, coke and a certain amount of coal for drying and heating purposes, and power, which might come either from the Wilson dam or from the steam power plant. The final product which the plant now makes is ammonium nitrate, which was to be used, mixed with TNT, in explosives.

Besides ammonium nitrate, there are several other nitrogen compounds which could be produced, first of which may be mentioned ammonium sulphate. This would necessitate setting up sulphuric acid units which were shipped from the Old Hickory plant. Another product, in the making of which we would employ phosphoric acid, would be ammonium phosphate. Another product which could be made there, by a method which we have worked out at the Fixed Nitrogen Research Laboratory, is urea. This material is manufactured at the present time in Germany and has been manufactured to some extent in this country. It is used at the present time, in the largest quantities, as a stabilizer for celluloid, and because of the size of the moving picture industry, considerable quanities of urea are used for that purpose. It is our belief that this material is being imported from Germany. We have tried to work out at our laboratory a process for this material, which we believe is somewhat similar to the process used in Germany, although we believe we have made improvements on the process used by the Germans.

Ammonium Nitrate as a Fertilizer

Then we have ammonium nitrate, which might well be made in certain quantities even during peace time, because it is used in peace time in permissible explosives and might work to some extent into fertilizer products. The main problem with ammonium nitrate as a fertilizer compound is that although it is an excellent plant food, nevertheless it is a very deliquescent substance. We have made a number of experiments in regard to the various possibilities of ammonium nitrate as a useful component of fertilizer products. We have gotten up methods for graining and oil-coating the ammonium nitrate, and it might be sold in that form. We have also experimented with a double salt of ammonium sulphate and ammonium nitrate. This double salt is less deliquescent than the ammonium nitrate, although not perhaps entirely satisfactory. Another method is to mix potassium chloride with ammonium nitrate. The two salts react together to form a mixture which is non-deliquescent, and that material contains two substances which are useful in fertilizer and which are used in fertilizer practice. Still another method is to mix ammonium nitrate and potassium sulphate together.

Use of Cyanamide in Fertilizer

Since the total capacity of this plant in the form of cyanamide, which is the cheapest form of nitrogen which it produces, would be 220,000 tons, it is not

*Abstracted from Dr. Tolman's testimony before the Military Affairs Committee of the House of Representatives in considering Henry Ford's offer for the Muscle Shoals plant.

believed that any large proportion of the product of the plant could be sold as cyanamide. The material cannot be used in mixed fertilizers, for the following reasons: If used in large amounts, it reacts with the acid phosphate to destroy its availability and it is also likely to produce dicyanodiamide, which is a substance poisonous to plant life. It can, however, be used in quantities of about 50 lb. to the ton of mixed fertilizer, but that would not absorb anywhere near the whole production.

We have made experiments which show that it can be more successfully mixed with basic phosphate, a material now produced by the Tennessee Coal & Iron Railroad Co. in Birmingham, and that it can be mixed with Thomas slag, a material which has been imported from Europe, and that it can be mixed with calcined phosphate, a new material which is not yet on the market.

Production of Organic Chemicals

Nitrogen, when fixed in the form of cyanamide, is combined directly with the carbon atom, and that leads to the possibility of the production of a variety of chemicals which could not be produced by other methods of nitrogen fixation. We believe the plant could produce quite a variety of organic chemicals.

Additions to the plant would have to be made in varying amounts to manufacture this variety of products. Some of the addditions would be relatively unimportant, such as putting in hydrating and oiling equipment for oiling the cyanamide. To put in phosphoric acid furnaces to make the ammonium phosphate would be more expensive.

One of the special chemicals that can be made with the help of nitrogen in the cyanamide form is nitroguanidine, which is a substance that the Ordnance Department is now experimenting with as a constituent of smokeless powder. Nitroguanidine can be obtained from nitrogen only in the cyanamide form. It is believed that there is a considerable possibility that nitroguanidine will be an important constituent of smokeless powder in the future. It was used by the Germans to some extent during the war. At the present time the only place on this continent where you can get the material to make nitroguanidine is the plant of the American Cyanamid Co. at Niagara Falls, Canada. If the smokeless powder used in the future should contain 50 per cent of nitroguanidine, which is perhaps an upper limit, the amount necessary to keep 100 divisions in the field per annum would be far larger than the total output possible at the Muscle Shoals plant. The reason why this material is a desirable substance for smokeless powder is because it has a high explosive force and yet explodes at a very low temperature, is a pure chemical substance, and is non-deliquescent.

A statement as to the possibilities of commercial success in the operation of the Muscle Shoals plant for the production of commercial fertilizer is a difficult matter, because it is trying to make predictions with regard to the future. However, the Fixed Nitrogen Laboratory feels that with ammonium sulphate at its present market price, in the neighborhood of $50 per ton, if the Muscle Shoals plant is to be run commercially to produce ammonium sulphate as its main product, the plant cannot be run and made to pay expenses.

If the Muscle Shoals plant be regarded as mainly producing ammonium sulphate, then with the price of ammonium sulphate at $65 a ton, the Fixed Nitrogen Research Laboratory feels that the plant can just about pay expenses and perhaps make a little profit, provided whoever runs the plant charges himself with a low enough figure for the water power which he uses and does not make his capital charges too high. The plant might about break even, with ammonium sulphate selling at $65 a ton, assuming a power cost of about three-quarters of a mill per kilowatt-hour and capital charges on a sum not larger than five or ten million dollars. These are our best guesses, because one cannot make precise predictions in a field of this kind.

As to the possibilities of the Muscle Shoals plant, if the plant be developed for a variety of materials, including ammonium nitrate, ammonium phosphate, urea and special chemicals of various kinds, under these circumstances, I think the plant can be made a commercial success, provided the man who obtains it surrounds himself with the proper chemical and scientific talent.

Research on Wood Conservation and Economy in Painting Planned

The Engineering Division of the National Research Council has projected a "paint on wood" research which is now being planned by the secretary of this division and G. H. Pegram and A. H. Sabin, members of a special committee responsible for the project. It is hoped that a committee will be organized representing the committee of the Engineering Foundation, American Institute of Architects, National Lumber Manufacturers Association, with representatives of painters, furniture manufacturers, piano and vehicle manufacturers and other principal users of paint and wood who will cooperate through the National Research Council in the investigation which will probably be done experimentally at the national Bureau of Standards and the Forest Products Laboratory.

Arrangement has been made with the two government laboratories named for contribution of their information and assistance regarding wood or wood treatment and paint and paint testing respectively. Among the objects sought are: Control of dimensional changes of wood due to absorption and loss of moisture; preservation of wood for economic reasons, including conservation of forests; economies in use of protective and finish coatings for wood and of the labor required for their application.

The research is to be put in the immediate charge of a well-trained technical man of varied experience, one who has not been connected directly with the lumber, wood-working or paint industries. Principal financial support aside from contributions made directly or indirectly by governmental bureaus, Engineering Foundation and National Research Council, is to be sought from producers and workers of wood and large users of protectives. Estimated cost is $8,000 to $12,000 a year for ten years. The Engineering Foundation or National Research Council will act as treasurer to receive and disburse funds.

New Metalliferous Solvent Reported Developed in Australia

Australia is preparing for commercial use a newly developed substance known as fibroferrite, according to advices to the Department of Commerce. It is said to possess valuable properties as a solvent. Its composition is given as follows: Ferrous sulphate, 50 per cent; oil of vitriol, 15 per cent; ferric sulphite, 10 per cent; alums and sulphur, 20 per cent; inert material, 5 per cent. The substance is said to possess properties which make it valuable in connection with the manufacture of red oxide of iron, disinfectants and dyestuffs.

Technical News of the Week

Current Events in the Chemical, Metallurgical and Allied Industrial Fields—Legislative Developments—Activities of Government Bureaus, Technical Societies and Trade Associations

Industries Offer Full Aid in Dye Investigation—Senator King Repeats Monopoly Charges

Monopoly, interlocking directorates, trusts, and similar appellations and charges constitute the basis of much of the attack made on the dye industry by Senator King. This is perhaps as conspicuous a point as has been raised during the past week in the proceedings before the Senate committee on investigation of this industry.

In contrast with the vitriolic attack upon the industry is the promise by Francis P. Garvan, of the Chemical Foundation, that the committee would be assisted in every way by presentation of any records or appearance of any person that might assist the investigators. The representatives of the chemical industries making dyes urge that no chance be lost to make the fullest possible presentation of the facts in the situation, as they state this will go far to dispel any feeling of improper relationship within the ranks of American dyestuff manufacturers.

It is charged by Mr. Garvan that the attacks made upon this industry can be traced back to an organized campaign of the German dye monopolies to block development of the domestic industry in the United States. This basis of discussion falls within the scope of the inquiry, as it is authorized to include not only a study of the domestic dye industry itself, but also the practices of dye importers.

The decision of Senator Shortridge of California to appeal to President Harding and Secretary of State Hughes to take prompt action to exercise whatever right the United States has to reparation dyes was made known informally at the close of Friday's session, after Albert M. Patterson, president of the Textile Alliance, had emphasized, in sworn testimony, the necessity of prompt action by the United States Government to prevent interruption of the supply of reparation dyes to the textile industry of the United States.

The State Department, in December last, terminated an arrangement whereby the Textile Alliance acted as agent for the department in importing reparation dyes allocated to the United States by the reparations commission, and distributed these dyes to the American textile trade. Since then, Mr. Patterson said, the reparations commission has declined to sell such dyes to private individuals and will soon cut the supply off altogether unless the United States Government will nominate some agency to continue or resume importation and distribution for the United States. Unless the government acts, therefore, Mr. Patterson said, the German dyes needed here will be furnished by the German dye cartel or trust instead of the reparations commission, at prices dictated by the German monopoly.

"I intend to call upon the President and the State Department, probably tomorrow, and urge that if the United States has a legal right to these dyes, the government proceed promptly to exercise that right," said Senator Shortridge. "I shall recommend that some government body or some agency be nominated to import and distribute those dyes in the United States, assuming, of course, we have a right to them. Personally, I am inclined to think we have."

Chemical Foundation Welcomes Investigation

Francis P. Garvan, former Alien Property Custodian, and now head of the Chemical Foundation, announced early in the hearing that "on behalf of myself and anybody connected directly, indirectly or remotely with the Chemical Foundation, I make haste to waive consideration of any kind whatsoever. We have been here trying for two years to have an investigation of this sort started, and while, of course, the thought never entered our heads, we are only too happy to place ourselves at your service without any consideration being asked or expected."

Senator King contended in substance that the average price of dyes in the American market today is much above pre-war prices and that the prices of intermediates have advanced in proportion. This advance he declared largely was due to special tariff and embargo legislation which he said had been passed for the benefit of the American dye industry.

Senator King declared that the Allied Chemical & Dye Corporation and the du Pont interests today have "practical control" of the manufacture of intermediates in this country. He attacked the Textile Alliance, declaring that "if it is not dominated by the American dye interests, it is working hand in hand with them to impose upon the textile industry extortionate and exorbitant prices."

He declared that it is economically wrong to prohibit importations either of intermediates or the finished products. If tariff protection is necessary, it should be "fair and just," he said. Propaganda for an embargo on importation of dyes has been and is being carried on, Senator King charged, by the Chemical Foundation, the Textile Alliance and the American Dyes Institute, which he described as "alleged eleemosynary institutions." The first, he alleged, controls all former German dye patents and formulas in this country; the second, he said, has controlled the distribution of reparation dyes in the United States, and the third, he charged, made it possible for American dye makers to "meet and agree as to prices, limit territory, restrict and regulate production and to prevent excess production."

King Questions Motives of American Dyes Institute

Senator King said the American Dyes Institute had no authority in its charter to carry on the activities he charged to its account, and also said the Textile Alliance has been acting outside the authority conferred upon it by its charter. The latter, he said, could be set aside in the courts, as a result. He further alleged that the Textile Alliance is under the domination of the Allied Chemical & Dye Corporation and the du Pont interests, adding that on the advisory committee of the Chemical Foundation and on the executive committee of the Textile Alliance are members of the "Allied" and of the du Pont interests. The du Ponts, he said, were the largest subscribers to the stock of the Chemical Foundation. The latter, he said, was conceived by Mr. Garvan and Joseph H. Choate, Jr.

The Chemical Foundation, said Senator King, has expended considerable money in propaganda. Mr. Garvan challenged a statement by King that the Foundation controlled the patent for manufacture in this country of synthetic indigo, informing Senator Shortridge that this patent lapsed years ago.

Condemns Seizure of German Patents

With the aid of a chart, Senator King sought to point out the connection between the office of the Alien Property Custodian and the organization of the Chemical Foundation. Francis P. Garvan, president of the Chemical Foundation, King said, was Alien Property Custodian; Joseph H. Choate, Jr., general counsel for the Foundation, was a dollar-a-year man in the office of the Alien Property Custodian; Ramsay Houget, patent attorney for the Chemical Foundation, was a dollar-a-year man in the office of the Alien Property Custodian; the trustees of the Foundation constituted the advisory sales committee of the Alien Property Custodian's office.

Senator King said that after the armistice, the Alien

Property Custodian, then A. Mitchell Palmer, sold, by authority of former President Wilson, 4,500 German patents to the Chemical Foundation for $250,000, although "I have been told that they were worth from $10,000,000 to $50,000,000."

Mr. Garvan was chief of the bureau of investigation in the office of the Alien Property Custodian when the patents were sold, it was developed, and later succeeded Palmer as Custodian.

The sale, Senator King further charged, was made to "officials who participated in the sale and this would be prima facie evidence of fraud in the case of private individuals."

Claims That Textile Alliance Is Aiding Monopoly

The Textile Alliance, Inc., he charged, is working "hand in glove with the domestic dye companies of the United States and is aiding them in maintaining a monopoly." Referring to the former control over the distribution of German reparation dyes in this country by the Alliance, Senator King declared the organization had acted far beyond the power of its New York state charter of incorporation and said the State of New York should proceed to disincorporate it. The Alliance, he claimed, is carrying on an aggressive campaign at Washington to continue as the sole importing agency of German reparation dyes.

In answer to questions from Senator Sterling of the subcommittee, Senator King denied any hostility to the American dye manufacturers, asserting he was not opposed to "fair and reasonable" tariff protection for them, and insisting he wished them to prosper. He declared his sole object was to attack the monopoly which he belives exists, and denounced all monopolies.

Harding Asks Definite Action on Dye Situation

The following letter written to Senator Frelinghuysen, of New Jersey, by President Harding was presented by Senator Frelinghuysen to the Judiciary sub-committee, of which Senator Shortridge, of California, is chairman.

Mr. Fleisch's full name is F. A. Fleisch and he is vice-president of the Textile Alliance, Inc.

> I have been going over the memorandum left with me by Mr. Fleisch of the Textile Alliance. I have also taken the matter up with Under Secretary Fletcher, and will pursue the matter further immediately upon the return of the Secretary of State. At the moment my best judgment is that we will get no effective arrangement made except through a resolution by Congress. I quite agree that we ought to get the benefit of such reparation credit as might come to us through the German export of dyes to this country, through the reparation commission, and we ought to protect our textile manufacturers against the grant of undue advantage to their competitors in the Old World. It would be easy to do this if Congress had not tied the hands of the administration in dealing with the reparation commission. I am writing to suggest that you confer with some of your associates regarding a resolution which will deal with the dye question definitely and directly.

Edgar Nathan of New York City, counsel for Kuttroff, Pickhardt & Company, Inc., importer of dyestuffs, obtained permission to make a statement in reply to what he termed as "unjust and misleading statements" made regarding his clients by representatives of the Textile Alliance, Inc. The officers and directors of his company, he said, are American citizens with a long record of honorable and satisfactory dealing with American consumers of dyes.

Mr. Nathan said his clients had dealt largely in dyes of American, English, French and Swiss manufacture as well as German dyes and that today their principal business is in American dyes. For many years they had the exclusive sales rights in the United States and Canada of the products of the Badische Anilin & Soda Fabrik of Germany, now one of the principal parts of the German dye cartel. Mr. Nathan said this company was not a member of the German cartel when first its relations with his clients began.

Practically every attack made upon the American dye and organic chemical industry can be traced back to a campaign of the German dye cartel, or monopoly, to block development of the industry here in order to regain control of the American market, Francis P. Garvan declared.

Blames German Intrigue for Situation

Mr. Garvan presented to the committee a story of German intrigue, beginning long before the war and continuing today, to expand in the United States German at the expense of American business. The German dye trust, he charged, really controls the business and property of its agents in this country.

The reparation system made it possible, Mr. Garvan explained, to supply dye consumers in this country with the 10 per cent they need.

"If we can continue to get this 10 per cent from the Germans through the reparations commission, the textile trade can be supplied reasonably," said Mr. Garvan. "But there is a danger that unless this is done, the textile trade will become impatient. The German dye cartel hopes to be in a position to supply us this 10 per cent on its own terms so that it can be used as a club upon the American textile trade and upon Congress to force us to take 100 per cent."

Defends Chemical Foundation

"Expressed in a few words, the main criticism against the Chemical Foundation seems to be that I, as Alien Property Custodian, transferred to myself or the Chemical Foundation, of which I was president, patents which some say were worth $1,000,000 for $250,000, so that by the German process of reasoning I derived a profit of $9,750,000.

"Senator King said we had no right to seize or sell this property; that it was in violation of the treaty of 1828. The United States Supreme Court decided in a case brought against me as Alien Property Custodian that the treaty applied only to German merchants actually in this country at the time war came on. We seized no property of any German citizen residing in America, except in the case of aliens interned because of activities against the United States Government."

Motives which caused the Alien Property Custodian to seize during the war German patents for the manufacture of dyes and drugs and to be certain that they were placed in American hands were summarized by Mr. Garvan thus:

1. Decision to make United States industry independent of the German dye trust so that no foreign power would control dyestuffs, key of many industries.
2. Resolve that the public health in the United States should not be dependent upon drugs the manufacture of which was controlled abroad.
3. Necessity of providing the United States with adequate chemical foundation for national defense.

When the United States became a belligerent, Mr. Garvan said, it was determined as a matter of national policy to seize and sell to American citizens German-owned property, including patents. The first sale by the Alien Property Custodian was the Bayer Company, manufacturer of aspirin, then owned by one of the six members of German dye cartel, he explained.

Garvan Tells of Sale of Patents

When it came to the question of disposing of the patents of the other five German trust members, it was recognized that to sell them at public auction would be dangerous, as they might fall into unfriendly or speculative hands. They were, accordingly, sold, with approval of the President, to the Chemical Foundation, which issues licenses for manufacture under the patents held by it and has never refused a license to any American manufacturer, he said.

The value of these patents, Mr. Garvan testified, was most uncertain, as in the first place they did not give the key to manufacture and, in fact, were worthless without expenditure of large sums of money in research work and for the establishment of a manufacturing plant. That American manufacturers were able to make use of these patents was a "great triumph" for American industry.

U. S. Chamber of Commerce Referendum Vote Shows Opposition of Business to Bonus

A referendum vote of the membership of the Chamber of Commerce of the United States commits the organization definitely in opposition to the cash bonus for ex-service men. A two-thirds majority of votes cast is necessary to commit the Chamber. In this case the vote against the bonus was 72 per cent. The vote will be placed immediately before Congress, now considering veteran legislation.

Although the Chamber had declared previously at two annual meetings against the cash bonus, the referendum ballot was sent out 6 weeks ago, with the desire on the part of the Chamber, according to Elliot H. Goodwin, a vice-president, "to be perfectly fair and to record any change in public sentiment if change there had been." Votes were cast by business organizations in 375 cities, 46 states, in the District of Columbia, Alaska and Hawaii, and by American Chambers of Commerce in Cuba and Mexico. Both classes of the National Chamber's membership, local chambers of commerce and trade associations, recorded themselves again the bonus by a more than two-thirds majority, although the vote of the trade associations was the heavier. The vote of the local bodies comprising the membership of the Chamber was even more strongly opposed.

The Chamber also committed itself in favor of a national system of reclamation through adequate federal appropriations to afford ex-service men an opportunity to cultivate the soil and of national legislation and appropriations to enable ex-service men to obtain vocational education.

General Fries Declares Continuation of C.W.S. Not Incompatible With Treaty

The treaty regarding submarines and gas adopted by the Limitation of Armament Conference does not attempt to abolish any service nor impose any limitations on research, development or proving, or even upon the accumulation of supplies of gas or any other materials of chemical warfare. The treaty simply prohibits "the use in war of asphyxiating, poisonous or other gases and all analogous liquids, materials or devices . . . ."

This is the interpretation of Brigadier General Amos A. Fries, chief of Chemical Warfare Service, in a statement regarding the effect of the action of the Conference on that branch of the Army. The statement continues:

"The good faith of the United States cannot be questioned if it continues the Chemical Warfare Service exactly as now constituted and doing exactly the same work as it is now doing. It is now, and would be then, simply a precaution against any other nation breaking its plighted word. There would seem to be less right to question the good faith of the United States for keeping its Chemical Warfare Service than to question its keeping its agreement not to use submarines improperly against merchant shipping, for the reason that submarines are constructed, maneuvered and supplied solely for the purpose of offensive action. Offensive action against merchant ships requires no different training, no different supplies or no different machinery than does the use of submarines against battleships.

"It is sometimes argued that we should keep up in research, but that it should not be done in a service called Chemical Warfare. If we attempt to camouflage preparations, we are immediately open to charges of perfidy in that we are secretly studying the use of gas while openly declaring that we do not intend to use it in war. That charge would be practically impossible to controvert. That a man is forbidden to carry a pistol does not in any way prevent his keeping one in his home and under proper regulations indulging in target practice so that he may successfully use it to keep out intruders. That is unquestionably the position of Great Britain and France, or Mr. Balfour and Minister Sarraut would not have had their statements to that effect recorded and made public as a part of the proceedings of the Conference. Proper preparedness is never a threat of aggression.

"It is submitted that the above is the patriotic and only proper interpretation of the treaty, and that no consideration should be given to any other interpretation."

Ladies Conduct Interesting Meeting of Chicago Section, A.C.S.

Each year the ladies of the Chicago Section of the American Chemical Society are given full charge of one regular monthly meeting. This year Feb. 24 was selected, and the enthusiastic attendance threatened to tax the seating accommodations at the City Club.

Miss Elizabeth Weirick, presiding, introduced the speaker of the evening, Miss Ruth O'Brien, associate professor of textile chemistry at Iowa State College. The opportunities for chemists in modern cleaning and dyeing establishments were pointed out by Miss O'Brien in an instructive and interesting manner. Through her intimate knowledge of conditions in cleaning and dyeing establishments throughout the country the speaker was able to indicate most convincingly the problems requiring scientific knowledge for their solution. Although essentially chemical in its nature, dealing as it does with animal and vegetable fibers, stains, cleaning agents, bleaching and finishing processes and dyes—this widespread industry engages very few chemists.

Miss O'Brien outlined the processes employed at the present time and showed how many of them had developed empirically. Like many other industries, the details of the processes vary from plant to plant, each operator being confident that his success lies in his own trade secrets. At the present time, however, the need for scientific counsel is beginning to be realized and real progress should result from the interest shown by the National Cleaners' and Dyers' Association. Miss O'Brien has been co-operating with this association and has just completed a short course in cleaning and dyeing at Iowa State College for members of the Iowa State Association.

The usual group meetings were also conducted by the ladies, the topics being as follows: "Standard Arts," by Miss Mary Hall of the Weyman-Bruton Co.; "Chemical Changes in Fats in Cooking," by Miss Katherine Blunt, University of Chicago; "A New Insight Into the Bromination of the Double Bond Between Carbon Atoms," by Prof. Ethel M. Terry, University of Chicago; "Chemical Analysis of Blood," by Dr. Chi Che Wang of the Michael Reese Hospital.

Industrial Developments of the Week

Rubber — The Erie Tire & Rubber Co., Sandusky, Ohio, has increased its operating schedule to a 24-hour basis for an indefinite period.

The Goodyear Tire & Rubber Co., Akron, Ohio, has increased production from 20,000 to 22,000 tires a day and will maintain this schedule for an indefinite time. About 500 men have been added to the working force.

The Seiberling Rubber Co., Portage, Ohio, is arranging for an immediate increase in manufacture from 839 tires a day to 1,265 tires, with corresponding advance in inner tube production from 1,000 to 1,500 per day.

Leather—Robert H. Foerderer, Inc., Philadelphia, Pa., has increased production 137 per cent as compared with this time last year. The number of employees at the plant is now 122 per cent greater than in March, 1921.

Oil—The Empire Refineries, Inc., is arranging for the immediate resumption of production at its plant at Gainesville, Tex. Other refineries of the company are increasing their outputs.

The Waco Refinery, East Waco, Tex., has placed its plant on a production basis of 2,000 bbl. of oil per day.

Ceramic—The Robinson Clay Products Co. has placed all of its plants in this district on a full running time basis. Orders on hand insure this operating schedule for some time to come.

Iron and Steel—The Gulf States Steel Co., Birmingham, Ala., has blown in its last blast furnace, following an extended idle period. The unit will be used for pig-iron production for the ingot mills of the company.

The Carnegie Steel Co. has blown in a blast furnace at its plant at Clairton, Pa., and plans to place three other units in service at an early date. The furnaces have all been out for more than a year.

The Hanna Furnace Co., Cleveland, Ohio, has relighted its blast furnace at Dover, Ohio, which has been out for

the past 13 months. About $600,000 has been expended for repairs and betterments. The plant will give employment to 150 men.

The Tennessee Coal, Iron & Railroad Co., Birmingham, Ala., will soon place its No. 4 furnace at Ensley, Ala., in blast, following a shut-down for some time past. The unit will be used for iron production for the open-hearth furnaces. The company is operating its tie-plate plant and car works under full production. The rail mill is increasing operations and the ingot department is now operating at about 77 per cent normal.

The Atlas Steel Co., Dunkirk, N. Y., has resumed operations at its plant, following a period of curtailment. Employment will be given to a large force of men.

The Glasgow Iron Co. has resumed operations at its seven puddling furnaces at the Universal Midland plant, Pottstown, Pa.

The Bethlehem Steel Co. has resumed operations at another open-hearth furnace at its Steelton, Pa., works, making six of nine furnaces now in service.

Cement—The Texas Portland Cement Co., Dallas, Tex., is arranging plans for capacity production at its mills early in March. The plant is running on a 24-hour basis, giving employment to about 250 men.

Coke—The Mt. Pleasant Coke Co. has resumed operations at its Beatty plant at Mount Vernon, Pa. The present capacity will be increased at an early date. The company recently fired over 300 ovens at its plant at Carpentertown, Pa.

The H. C. Frick Coke Co. is planning to increase operations at its plant in the vicinity of Mount Vernon, Pa.

Metals—The American Smelting & Refining Co. is arranging to increase the working force at its Perth Amboy, N. J., plant by more than 200 men. The company has taken a large smelting contract from the Phelps Dodge Corporation, New York, which will be handled at the Perth Amboy plant.

The Anaconda Copper Co. has resumed operations at its copper refinery at Great Falls, Mont., following a recent increase in output at the electrolytic plant. It is planned to give immediate employment to about 1,000 men, increasing shortly to 1,200 men. Normally, the smelting would give employment to 1,500 men.

The Mt. Shasta Gold Mining & Milling Co., Montague, Cal., has resumed production at its Black Hawk silver properties. Plans are under way for enlargements in the mill to increase the present capacity.

The Butte & Superior Copper Co., Butte, Mont., is planning to increase its present working force from 700 to 1,000 men. The company is now operating at the Black Rock concentrator at about 80 per cent of capacity and will bring production up to normal within the next few weeks.

Application of Muscle Shoals Power to Chemical Processes Denounced

The worst possible use to which the power at Muscle Shoals could be put, in the opinion of Colonel Hugh Cooper, would be its application to chemical processes. This was one of the main reasons which he advanced, while testifying before the Military Affairs Committee of the House of Representatives, as to why Henry Ford's offer for Muscle Shoals should not be accepted.

"It is not wise from the standpoint of public interest in the South to take out of its water-power reserves so great a horsepower for chemical purposes," he declared. "If this plan is consummated, the people in the South who are clamoring for the acceptance of this proposal soon will be crying for its abrogation.

"Twenty years ago at Niagara Falls they started to build what is now a 400,000-hp. plant. At that time they could not get a market for the power, so they took in the chemical people. Chemical interests and the water-power interest tied up and built up a great industry, all in chemistry. As a result, this water power at Niagara Falls did not get as far as Buffalo, 23 miles away. Two years ago Buffalo had to pay $10,000,000 for a steam plant, yet the city is within 23 miles of one of the greatest water powers in the world.

"Now there is a wide movement in the State of New York to alter the water-power situation at Niagara Falls. At this very moment they are passing legislation that is absolutely conclusive and compelling so that the power generated at Niagara Falls can be distributed throughout the tributary territory and no more of it go into chemistry.

"I do not want to be understood as saying that that these chemical industries at Niagara Falls are a curse to the country. They have accomplished a great good and the country would have been in bad shape during the war without all of them. There is a limit, however, to the water power which should be assigned to chemistry. The people of New York, after 20 years of experience with the chemical industries, are storming the Legislature to stop the use of power in chemistry in a territory that is buying coal for power use. Chemical industries do not use much labor. Take the Aluminum Company, for example. It has 150,000 hp. in its works at Messina. The town is no larger than it was 20 years ago. The South needs cheap, reliable energy to be distributed over a large territory. If you put the power at Muscle Shoals into chemistry, it will be like taking vertebræ out of a man—there would be nothing to which the ribs could be fastened. When these people get over their present spell, they will see the errors in their enthusiasm. I think it would be a tremendous calamity to the South if the greatest water power it has should be taken out of the field of public utility for 100 years."

J. W. Worthington, chairman of the executive committee of the Tennessee River Improvement Association, in his testimony before the committee, when called upon to explain if it would be wise to permit the No. 1 plant to be converted into an automobile factory, said in part:

"No prudent person would use the Haber process in view of what happened in Germany a few months ago when the Oppau plant blew up. It is rather singular, if that plant could be operated successfully—and admittedly it never has been—that the General Chemical Co., which designed it and which let the government have the process, refused Mr. Glasgow's proposal to take the plant for 3 years, when the United States would not charge a penny for its investment for the use of the plant if only the General Chemical Co. would agree to spend $500,000 in further development, investigation, research and operation. It stands today as a failure. At Syracuse, N. Y., byproduct hydrogen is available. The plant was located at Syracuse to be near the coke ovens. Suppose Plant No. 1 had proved to be a success. Even then it would not be operated by Mr. Ford. He would double it up with No. 2."

Joint Meeting of Middle Western A.C.S. Sections

A full program for the afternoon and evening of March 14 is planned for the joint meeting of the sections of the American Chemical Society co-operating in the publication of the *Chemical Bulletin*. The meeting is to be held at Northwestern University, Evanston, Ill., where excellent facilities are provided for all parts of the program. The afternoon general meeting will be addressed by H. E. Howe, editor of the *Journal of Industrial and Engineering Chemistry*, on "Chemistry's Publication Problem." The evening will be devoted to group meetings of the inorganic, organic, synthetic, biologic, educational and non-technical groups. Among the speakers at these group meetings will be H. I. Schlesinger of the University of Chicago, who will speak on "The Theory of the Chamber Process," J. A. Wilson of Milwaukee, on "The Analysis of Vegetable Tanning Materials," and Roger Adams, of the University of Illinois, on "Platinum Black Catalysts."

New Power Project for Pacific Coast

Application has been made to the Federal Power Commission for permission to construct the transmission line which will link the power systems of California with those of the Columbia River Valley. The application was filed by the California-Oregon Power Co., Medford, Ore. The transmission line for which license is asked is to extend from Prospect power house to Springfield, Ore., a distance of 100 miles.

American Institute of Chemical Engineers Announces Plans for Summer Meeting

The summer meeting of the American Institute of Chemical Engineers will be held at Niagara Falls, N. Y., June 19 to 22. Headquarters will be at the Clifton Hotel.

For the program of papers a symposium on acid manufacture is being arranged. This will include the manufacture and concentration of sulphuric, nitric and hydrochloric acids, as well as phosphoric acid. A number of excellent papers have already been promised for this symposium.

One day will be spent in Buffalo visiting the industries in that locality. Another day will be devoted to a lake trip to Toronto, Canada, and inspection of the chemical plants in that vicinity.

Technology of Lubricants Subject at Delaware Section, A.C.S., Meeting

An interesting address on the subject of "Why Oils Lubricate" was given by Prof. Robert E. Wilson, director of the Research Laboratory of Applied Chemistry of the Massachusetts Institute of Technology, at the Feb. 15 meeting of the Delaware Section of the American Chemical Society, at Wilmington, Del. The talk was based on the results of research work at the laboratory. Prof. Wilson pointed out the shortcomings of present specifications for lubricants and discussed the action of various lubricants in different uses.

C. F. Chandler Foundation Medal Presented to Edgar F. Smith

One of the most pleasant details attending the award of the Charles Frederick Chandler Foundation medal to Edgar F. Smith, president of the American Chemical Society, at Columbia University, March 2, was the fact that the token was presented by the man whose name and likeness it bears. In handing the medal to Dr. Smith, Dr. Chandler spoke of their long personal friendship and declared that there was no one to whom he would rather present the honorary award. He referred to the wonderful growth of Columbia University since 1864 when he became associated with it, a time when the student enrollment was 150 and the headquarters of the college were located in the deaf and dumb asylum.

In accepting the honor conferred upon him, Dr. Smith spoke reminiscently of his student days at Göttingen where he and Dr. Chandler studied under the same masters. He also mentioned the close relationship between Columbia University and the University of Pennsylvania, especially between the chemistry departments of the two institutions.

The Chandler medal is the result of a foundation established by the friends of Professor Chandler in 1908. Previous awards have been made to L. H. Baekeland, W. F. Hillebrand, W. R. Whitney and F. G. Hopkins.

Dr. Smith delivered an address on "Samuel Latham Mitchill—a Father in American Chemistry." Mitchill was the first professor of chemistry at Columbia College and the first Senator from the State of New York. It was particularly to his achievements in the field of chemistry, however, that the speaker gave attention.

Mitchill gained prominence in 1792 as the first public champion of anti-phlogiston views in America. He supported Lavoisier, whereas Priestley, who came to America in 1794, remained the protagonist for phlogiston until the day of his death. He gave a vivid picture of the controversy that raged. In 1797 Mitchill founded the *Medical Repository*, a journal originally intended to serve the medical profession but which later broadened its scope to take in the whole field of science. The *Repository* was strongly opposed to the phlogiston theory.

As a teacher, for such he was primarily, Mitchill was characterized by the extreme clarity of his methods and the breadth of his views and interests. It was his practice to introduce into his teachings all the new ideas and current developments in the state of the art. As professor of chemistry at Columbia he established a chemical museum in which were included exhibits of chemical products and minerals.

Among the earliest experiments conducted by Mitchill was his investigation of evaporation. In these experiments the first inklings of physical chemistry are discernible. It is worthy of note that the early chemists realized the importance and scope of this branch of the science but on account of the pressing needs of the country were forced to devote their energies to the practical applications.

Mitchill's mind was of a very speculative nature. His writings in 1802 still show the influence of the phlogiston theory but this later disappears. It was at this time that he published his belief that all matter consists of atoms, infinitely small, held together by balanced attractive and repellent forces. In his experiments on wood ashes he discovered the presence of potassium phosphate in the ash. As a result of these studies he conceived the conviction that potassium was combined with oxygen in potash and it is believed by some that this furnished Sir Humphry Davy with the clue that led to his isolation of metallic potassium.

Early in his career he had thought seriously of the causes of the decay of matter. His medical training no doubt added interest to his consideration of this problem. The most important result of his work was his conception of an imaginary element which would check organic decay and destroy the noxious products. He called this element septon, and believed it to be a combination of the "chlor" element of muriatic acid with oxygen. He declared that "septon is a fiend to animal life" and applauded the virtues of the oxychlorides of calcium and sodium as disinfectants. In this work, Mitchill was assuming the role of the present sanitary chemist and his work antedates the well known European "discoveries" by about 30 years.

He died in 1831, honored by more than 100 American and European scientific societies and famed for his work, not only in chemistry but in mineralogy, medicine, education and the public life of America.

Federal Board for Vocational Education to Fill Vacancy

The United States Civil Service Commission announces an open competitive examination for information assistant. Vacancies under the Federal Board for Vocational Education at $2,400 to $3,600 a year, and in positions requiring similar qualifications, at these or higher or lower salaries, will be filled from this examination, unless it is found in the interest of the service to fill any vacancy by reinstatement, transfer or promotion.

The duties of this position will consist of popularizing the activities and purposes of the Federal Board for Vocational Education through magazines, trade journals and the daily press and of winning public co-operation for the cause of vocational education and rehabilitation of persons disabled in industry or otherwise. It is desired that in addition to possessing journalistic qualifications, the appointee should have had trade and industrial connections and that he should be able to make personal appeals for co-operation by platform or otherwise to industrial, labor and agricultural organizations.

Competitors will not be required to report for examination at any place, but will be rated upon education and experience and published papers or articles prepared by them. Applications will be received on Form 2118 prior to March 28, 1922.

Government Needs Explosives Chemists

The United States Civil Service Commission announces that there are a number of vacancies in the Ordnance Department of the Army in positions of chemist qualified in the chemistry of explosives. These positions offer salaries ranging from $1,800 to $3,600 a year, depending upon the qualifications of the appointee and the duties to which assignment is made. Applicants are not assembled for written tests, but are rated upon the subjects of (1) education, training, and experience, weighted at 70 per cent, and (2) publications or thesis, to be filed with applications, weighted at 30 per cent.

Full information and application blanks may be obtained by communicating with the United States Civil Service Commission, Washington, D. C., or with the secretary of the U. S. Civil Service Board at the post office or custom house in any city.

General Sentiment of National Council Opposed to Metric System

The National Council of the U. S. Chamber of Commerce adopted a resolution rejecting the proposal for a referendum on the metric system at this time. An interesting discussion preceded the adoption of the resolution.

A point that had great influence on the gathering was made by George B. Chandler of the Connecticut Chamber of Commerce when he said: "If you will analyze the support of the affirmative on this question, you will find among all those proponents there is only one representative of industry. That is very significant. The others are representative of the theoretical."

W. C. Wilson, assistant to the president of the American Institute of Weights and Measures, made the principal antimetric argument. He read a concise statement from W. R. Ingalls, the president of the American Institute of Weights and Measures. Mr. Ingalls said that the greatest obstacle to the adoption of the metric system would be its cost to the people. In the manufacture of metals alone, the cost would be something like half a billion dollars, he said. Mr. Wilson, in his address said:

"If the metric system offers such extraordinary advantages as are claimed for it, is it reasonable to suppose that American manufacturers, who have stood in the forefront of industrial progress and who are thoroughly familiar with the metric system, are so blind to their own interest and so lacking in business intelligence that they must have it crammed down their throats by compulsory legislation?"

George B. Blow, of the Illinois Valley Manufacturers Association, who is a manufacturer himself, advocated the adoption of the metric system vigorously. "England is very much in the same condition as ourselves," he said. "She is clamoring for metric weights and measures because she has found out that the country is losing foreign business to the metric countries. England is finding out that Germany and other metric countries are getting business from them, particularly in South America. We have no right to vote down a proposition to submit anything to a referendum. This matter should go to referendum as recommended by the committee."

Charles L. Parsons, secretary of the American Chemical Society, among other things said: "I want to speak for a whole profession. The chemists of America are united in one immense society with 15,000 members. The chemists of America use the metric system daily. They are absolutely united in favor of it. I have no sympathy with the argument of cost. If we followed that argument we would be riding buggies while the rest of the world would be using automobiles."

Educational Conference on Business Training of the Engineer

The United States Commissioner of Education is calling a second public conference on commercial engineering on behalf of a committee on commercial engineering appointed by him to investigate business training of engineers and engineering training for students of business. The conference will be held May 1 and 2 at the Carnegie Institute of prominent deans of schools of engineering and of commerce and of engineers and business men who are nationally known for their interest in the reduction of the costs of production, distribution, transportation, etc.

Outstanding topics at the Pittsburgh conference will deal with the new problems that have recently arisen in modern industries, the solution of which demands a more scientific approach. This will include the training of the engineer for a better understanding of problems relating to community development and for the management of overseas engineering projects.

No Nichols Medal Award for 1921

No award of the Nichols Medal will be made this year, it is announced. The medal is awarded to the writer of the most exceptionally meritorious article appearing during the year in the journals of the American Chemical Society. The passing of the award is due to lack of articles of sufficient merit.

Personal

O. M. BUTLER, who was assistant director of the Forest Products Laboratory at Madison, Wis., has tendered his resignation, effective March 1. He will leave Madison for Washington, D. C., to join the American Forestry Association to direct its technical activities.

ERNEST W. DEAN has resigned as petroleum chemist of the Bureau of Mines, Pittsburgh, Pa., to join the staff of the Standard Oil Company of New Jersey as director of the standard inspection laboratory. Mr. Dean's successor in charge of the Pittsburgh petroleum laboratory of the Bureau of Mines is N. A. C. Smith, formerly of the Washington office.

FRANK R. ELDRED and FREDERICK C. ATKINSON announce the organization of Eldred & Atkinson, Inc., chemical adviser and engineer, with offices at 48 East 41st St., New York City, and 1857 Gent Ave., Indianapolis, Ind.

HENRY HARNISCHFEGER, president of Pawling & Harnischfeger Co., Milwaukee, Wis., left on Jan. 28 on a combined business and pleasure trip around the world. He is accompanied by Mrs. Harnischfeger, and they plan to go to Japan, the Philippines, China, Burma, Ceylon, India, and up through the Suez Canal to Naples and Europe.

PIERRE E. HAYES, formerly with Linde Air Products Co. and the Prest-O-Lite Co., announces the establishment of a consulting engineering office in the Ellicott Square Building, Buffalo, N. Y. His services will be available for the conduct of research, development, test or survey work involving chemistry, physical chemistry, thermodynamics or engineering economics.

DAVID W. JAYNE and HERBERT G. SIDEBOTTOM, formerly associated with The Barrett Co., New York, have entered business together under the corporate name of Jayne & Sidebottom, Inc. They will act as manufacturers' agents in the sale or purchase of chemicals commonly used in the textile, paint, rubber, dye, chemical, pharmaceutical, paper, leather and allied industries. Their offices are in the Whitehall Building, 17 Battery Place, New York.

COLONEL E. LESTER JONES, director U. S. Coast and Geodetic Survey, Washington, D. C., spoke on March 2 at the Franklin Institute on "Surveying From the Air."

L. CHARLES MAZZOLA, assistant superintendent of the Metal & Thermit Corporation, spoke on March 3 at a meeting of the chemical society, which was held in conjunction with the mechanical society of Polytechnic Institute. His subject was "Thermit and Its Application."

EDWIN J. PRINDLE, patent attorney, of Prindle, Wright & Small, New York, was presented by the Commissioner of Patents with the pen with which President Harding signed the Patent Office bill.

KIRBY THOMAS of New York has been examining the limestone deposits in Parkers Landing, Butler County, Pa.

The American Institute of Mining and Metallurgical Engineers announces the election of new officers of the Institute of Metals Division, as follows: Chairman, W. B. Price, Scovill Manufacturing Co., Waterbury, Conn.; vice-chairman, George K. Elliott, Lunkenheimer Co., Cincinnati, Ohio; secretary and treasurer, W. M. Corse, Monel Metal Products Corporation, Bayonne, N. J. The executive committee is composed of George K. Elliott, Lunkenheimer Co., Cincinnati, Ohio; C. T. Bragg, Michigan Melting & Refining Co., Detroit, Mich.; H. M. Lane, H. M. Lane Engineering Co., Detroit, Mich.; Lawrence Addicks, New York City; William Campbell, Columbia University, New York City; J. A. Capp, General Electric Co., Schenectady, N. Y.; E. E. Thum, CHEM. & MET. ENG., Tenth Ave. and 36th St., New York City; George F. Comstock, Titanium Alloy Manufacturing Co., Niagara Falls, N. Y.; W. A. Cowan, National Lead Co., Brooklyn, N. Y., and H. M. Williams, General Motors Research Corporation, Dayton, Ohio.

Market Conditions

IN CHEMICAL, METALLURGICAL AND ALLIED INDUSTRIES

A Survey of the Economic and Commercial Factors That Influence Trade in Chemicals and Related Commodities—Prevailing Prices and Market Letters From Principal Industrial Centers

A Statistical Study of the Pulp and Paper Industry

The manufacture of paper pulp and its further fabrication into the various grades of paper is one of the chemically controlled industries for which accurate and comprehensive statistics are available. Through the services of the Federal Trade Commission, the commodity division in the Department of Commerce, and the active co-operation of the entire industry, paper manufacturers and consumers, and the general public as well, are provided with a reliable means for following conditions in this important industry.

These compilations prove beyond a doubt that the paper industry has already passed through the worst stage of the present business depression and is now distinctly on the road to improvement. To be sure, the total production figures for 1921 show a decrease of about 27 per cent as compared with 1920, but the real gain is in the monthly outputs. From Table I it will be noted that during the first 7 months of 1921 production dropped off at an alarming rate. From

TABLE I—DOMESTIC PRODUCTION AND SHIPMENTS OF ALL GRADES OF PAPER BY YEARS 1917 TO 1921

(Quantities in Net Tons.)

Month and Year	Monthly Production 1921	Monthly Production 1920	Monthly Shipment 1921	Monthly Shipment 1920
Total for All Grades				
January	420,468	650,293	385,923	646,715
February	407,966	564,500	383,679	532,336
March	440,777	641,343	416,668	656,658
April	422,012	634,402	425,584	622,913
May	383,995	645,413	386,671	662,587
June	403,657	657,322	405,959	668,082
July	370,429	658,518	379,672	657,360
August	442,519	654,158	448,054	652,998
September	477,926	643,018	489,128	648,295
October	542,408	621,964	560,558	613,324
November	535,876	518,144	531,606	499,281
December	508,284	445,539	503,567	423,986

Year	Annual Production	Annual Shipments
1921	5,356,317	5,317,069
1920	7,334,614	7,284,535
1919	6,190,361	6,225,904
1918	6,051,523	6,089,776
1917	5,919,647	5,838,286

420,500 net tons in January the output fell to 370,500 tons in July. Since then, however, the industry has made a remarkable recovery and is now on a production basis which compares favorably with the average for the last 5 years. According to the announcement of the Federal Trade Commission, we produced 506,195 net tons of paper in January, 1922, while the 5-year average for that month is only 504,175 tons.

The trend of production in the paper industry is shown graphically in Fig. 1, which is taken from the Harvard Economic Service's recent report on "The Volume of Manufacture." The adjusted index of 100 is based on the monthly averages for 1919. In discussing the relation of output to productive capacity of the paper industry, Babson makes the following statement: "Operations for 1921 were in the neighborhood of 60 per cent, as against about 90 per cent in 1920 and the rough average of 80 per cent for the 20 years previous thereto. The industry presented no evidence of undue expansion during the war, but since 1919 has increased in capacity at a rapid rate. From 1899 to 1919 the machine capacity grew about 220,000 tons per year. In 1920, however, the capacity increased 900,000 tons over 1919, and in 1921 further increased 650,000 tons over 1920. The number of companies engaged in the business decreased slightly between 1914 and 1919. Production is now estimated at about 70 per cent of capacity. It should be noted that the present capacity exceeds any probable demands during this year."

Production of all grades of paper decreased in 1921 as compared with 1920, the percentage of reduction varying from 39 per cent in the case of wallpaper to 17 in the case of tissue paper. Bag paper, which includes that made into flexible commercial containers such as grocery bags and flour sacks, and fine paper, such as writings, bonds and ledgers, also had very high rates of decrease. Book paper, which includes all periodical paper and miscellaneous grades

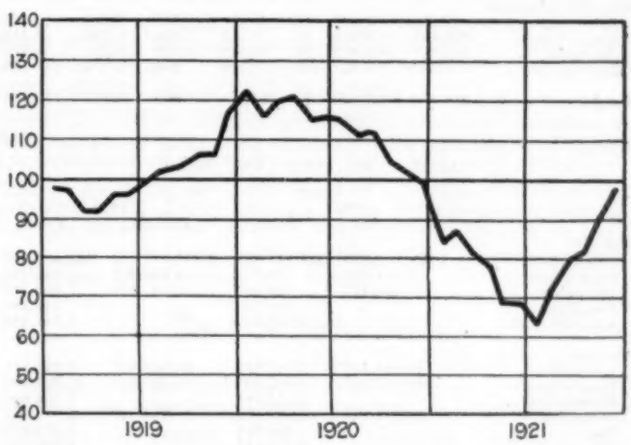

FIG. 1—THE TREND OF PRODUCTION IN THE PAPER INDUSTRY, 1919-1921

of machine finished, supercalendered and coated stock, decreased from 1,104,464 net tons in 1920 to 725,992 tons in 1921. It will be noted that stocks, on the other hand, were considerably larger during 1921 than in the preceding year.

Pulp Production and Stocks

A similar comparison of the production of wood pulp and the other kinds of pulp used in paper making is afforded by Table III. It will be noted that the decreases are in almost exactly the same proportion as in the case of paper. The bleached sulphite pulp shows the maximum reduction in output. Production for all grades of pulp in January, 1922, was 266,921 net tons, as compared with an average of 270,850 tons for the same month in 1919-1922. The Federal Trade Commission has the following to say regarding the ratio of stocks to average production:

"Comparing the stocks on hand at the domestic pulp mills at the end of January, 1922, with their average

CHEMICAL & METALLURGICAL ENGINEERING'S WEIGHTED INDEX OF CHEMICAL PRICES

Base = 100 for the year July 1, 1913, to June 30, 1914

This week	157.46
Last week	151.21
March, 1921	157
March, 1920	252
April, 1918 (high)	286
April, 1921 (low)	140

The index number has shown a gain of 6.25 during the past week and is now 14 points higher than the quotation for Jan. 25, 1922, which was the lowest level reached during the current year. This week's increase is due principally to the higher prices for ammonium sulphate, barium chloride, caustic soda and cottonseed oil. The only price reductions among the index commodities were for bleaching powder, soda ash and glycerine.

daily production based on the reports covering the years 1917, 1918, 1919, 1920, and 1921, the figures show that:

Ground wood pulp stocks equal 28 days' average output.

News grade sulphite mill stocks equal 9 days' average output.

TABLE II—PRODUCTION AND STOCKS OF PAPER BY GRADES IN 1921 AS COMPARED WITH 1920

(Quantities in Net Tons.)

	Production		Per Cent of Decrease in 1921	Stocks on Hand at the Mills — Maximum Quantity During the Year		Minimum Quantity During the Year	
	1921	1920		1921	1920	1921	1920
Total newsprint	1,226,189	1,511,968	19	41,789	27,955	23,015	16,934
Standard news	1,130,943	1,380,239	18	35,517	25,104	18,227	14,576
Book	725,992	1,104,464	34	40,253	28,434	28,880	20,826
Total paperboard*	1,664,931	2,313,449	28	70,780	53,104	57,169	38,249
Boxboard	1,122,336	1,378,166	19	35,233	25,451	28,696	16,361
Wrapping	651,605	831,889	22	62,811	35,800	45,241	19,570
Bag	130,863	211,923	38	3,792	3,595	2,885	2,015
Fine	242,485	389,322	38	41,143	32,260	33,389	27,127
Tissue	148,142	177,447	17	9,122	6,839	5,811	5,237
Hanging	69,725	113,824	39	10,522	3,027	4,799	960
Felt and building	286,111	366,941	22	13,553	14,116	6,513	6,585
Other grades	210,274	313,387	33	20,580	17,160	17,475	13,621
Total for all grades	5,356,317	7,334,614	27	297,337	214,396	244,657	165,340

*Figures for boxboard prior to March, 1920, were included under Total Paperboard.

TABLE III—DOMESTIC PRODUCTION AND STOCKS OF PAPER PULP IN 1921 COMPARED WITH 1920

(Quantities in Net Tons.)

	Production		Per Cent of Decrease in 1921	Stocks on Hand at the Mills — Maximum Quantity During the Year		Minimum Quantity During the Year	
	1921	1920		1921	1920	1921	1920
Ground wood Pulp	1,268,012	1,578,300	20	226,089	152,973	115,363	92,823
Sulphite, news grade	623,493	843,514	26	24,626	20,549	20,930	12,731
Sulphite, bleached	360,063	518,081	38	16,614	6,682	4,581	3,808
Sulphite, easy bleaching	62,344	72,394	14	1,774	1,386	581	569
Sulphite, mitscherlich	60,005	82,687	27	3,990	2,768	1,064	915
Sulphate pulp	148,165	212,888	30	9,354	7,850	6,200	2,248
Soda pulp	272,287	431,971	37	10,390	6,938	6,281	3,313
Other grades	7,069	7,821	10	208	238	15	26
Total for all grades	2,801,438	3,807,656	26	286,216	183,876	158,555	121,338

TABLE IV—IMPORTS AND EXPORTS OF PAPER (POUNDS AND VALUE) AND PULP (NET TONS)

Paper	1921		1920	
	Pounds	Value	Pounds	Value
Imports:				
Newsprint	1,584,962,674	$79,123,368	1,459,737,288	$68,600,950
Book paper	1,414,781	199,355	4,340,425	496,132
Wrapping	11,414,472	528,849	4,941,824	460,289
Hanging	.....	363,269	.....	353,791
All other grades	.....	3,039,230	.....	2,741,238
Exports:				
Newsprint	33,641,462	2,162,975	91,951,913	5,983,611
Book paper	40,167,065	5,892,609	95,689,512	13,765,694
Paperboard	.....	2,323,949	.....	5,553,094
Wrapping	26,044,152	2,293,892	61,264,501	6,994,381
Bag	.....	846,909	.....	2,593,459
Fine	.....	4,355,642	.....	8,908,230
Tissue	.....	1,080,380	.....	2,654,529
Hanging	.....	590,549	.....	1,251,743
All other grades	.....	6,143,155	.....	11,091,952
Total imports	.....	83,254,071	.....	$72,652,400
Total exports	.....	25,690,060	.....	58,796,693

Pulp	1921	1920	1919	1918
Imports	Net Tons	Net Tons	Net Tons	Net Tons
Chemical wood pulp:				
Bleached sulphite	95,206	128,206	42,755	16,757
Unbleached sulphite	233,064	344,969	239,952	253,454
Bleached sulphate	4,082	17,277	5,145	3,759
Unbleached sulphate	174,004	182,697	145,911	118,761
Ground wood pulp	190,744	233,148	202,253	185,478
Paper stock other than wood pulp	117,405	254,755	110,195	29,397
Total	814,505	1,161,052	746,211	607,606
	1921	1920	1919	1918
Exports	Net Tons	Net Tons	Net Tons	Net Tons
Domestic wood pulp	28,483	32,133	40,095	22,324
Rags and other materials made from vegetable fibers	20,206	42,282	27,271	16,121
Total	48,689	74,415	67,366	38,445

Bleached sulphite mill stocks equal 5 days' average output.

Easy bleaching sulphite mill stocks equal 3 days' average output.

Mitscherlich sulphite mill stocks equal 6 days' average output.

Sulphate mill stocks equal 17 days' average output.

Soda pulp mill stocks equal 9 days' average output.

Mill stocks of "other than wood pulp" equal 5 days' average output.

Total mill stocks of all grades equal 16 days' average output."

Imports and Exports

Recent increase in the total imports of finished paper, combined with a 50 per cent reduction in exports during 1921, has been a matter of considerable concern to paper manufacturers. Newsprint, the bulk of which is imported from Canada, is the only grade of which the United States is a heavy importer. In 1921 newsprint showed about a 10 per cent increase both in quantity and value. Our foreign trade in paper during 1920 and 1921 and in pulp during the period 1918 to 1921 is shown in Table IV.

The Outlook for 1922

The most pressing problem now facing the paper manufacturers is the need for reducing costs of production. Although costs have receded considerably from the peak reached in 1920-21, they are still much higher than in 1913. To quote a second time from Babson: "Briefly, the outlook for the paper industry during 1922 is for continued readjustment of costs to prices with, nevertheless, a somewhat better demand for manufacture than was the case during 1921. Production should average about 70 per cent, or 6,200,000 lb. The most active period will probably be during the spring and fall months, with very quiet conditions in the summer. The spring activity will not be so good as the fall activity, due to the presence of fairly high stocks. Moreover, an improvement in general business conditions during the fall will then furnish greater stimulation."

Volume of Manufacture Will Increase in 1922

In a detailed report on this subject published Feb. 25, 1922, the Harvard Economic Service makes the following statement regarding future manufacture:

"There is a growing conviction that 1922 will witness a substantial increase of industrial output. Underlying factors are undoubtedly improving; liquidation is proceeding relentlessly; wages are being adjusted; prices are gradually assuming greater stability; agricultural prices in particular are exhibiting a definite tendency to rise. As these factors exert their favorable influence, production will undoubtedly respond. It seems to be generally conceded that consumption for the past year and a half has materially exceeded production. Stocks have been steadily reduced and there has been an increasing resort to current manufacturing to supply current consumption. It is this fact which accounts fundamentally for the rise in the volume of manufactures since last summer. There is every reason to believe that the same forces will operate cumulatively to stimulate production during 1922. With the evident improvement in underlying conditions, a rise in the volume of manufacture during 1922 is confidently predicted."

Many Far-Western Engineers Are Unemployed

Walter V. Brown, manager of the Employment Service of the American Engineering Council, has received a particularly discouraging report from his Californian representative regarding employment conditions on the Pacific Coast.

"The great question," said this report, "is: What is to become of the large percentage of engineers, long out of work and likely to stay so? Engineers do not earn so much that they can be idle for a year with impunity. Many here have gone into other business and others are ready to do the same at the first opportunity. There have been too many engineers turned out by the universities in late years. The market is glutted and it will be a good reaction if we see fewer in the near future."

Annual Reports and Dividend Announcements

Air Reduction Co.—C. E. Adams, president, stated in a recent letter to stockholders that the gross income of the company decreased from $7,189,767.37 in 1920 to $5,338,869.17 in 1921; and the net profits earned on the outstanding stock, before federal taxes, decreased from $1,256,439.93 in 1920 to $630,524.24 in 1921. The latter sum, however, was sufficient to pay the regular dividends out of current earnings.

Among other developments reported in the annual report was announcement of the purchase of control in the National Carbide Corporation. This assures the company of an ample supply of carbide for its own acetylene charging plants as well as for customer demands. Through the purchase of the Compressed Carbonic Co. in Baltimore, the company enters the liquid carbonic field and has already made satisfactory progress. During the year a new oxygen plant was built in Pittsburgh and a new acetylene plant in the Boston district. Commercial production of the "Airco Ignition Gauge" began in October, its active principle, neon, being obtained as a byproduct in the operation of the company's oxygen plants.

Allied Chemical & Dye Corporation—The regular quarterly dividend of 1¾ per cent was declared Feb. 28 on the preferred stock of this company, payable April 1, 1922, to stock of record on March 15, 1922.

Atlas Powder Co.—For the year ended Dec. 31, 1921, this company reported a net income of $634,484, which after allowing for preferred dividends was equal to $1.71 a share on the $5,515,985 common stock. In 1920 the company earned $1,434,693 and paid $16.32 per share on its common stock.

President W. J. Webster, in his letter to stockholders, pointed out that during the last 4 months of 1921 the company had actually earned $15.20 a share on its common stock, but because of greatly reduced inventory could show only $1.71 in its report.

Celluloid Co.—A dividend of 2 per cent upon the capital stock of this company has been declared, payable March 31 to stock of record March 8.

International Salt Co.—The regular quarterly dividend of 1¾ per cent has been declared on this company's capital stock. The dividend is payable April 1, 1922, to stockholders of record on March 15.

National Lead Co.—The report of this company for the year ended Dec. 31, 1921, shows a net income of $3,481,512, as compared with $4,735,509 in 1920. After deducting preferred dividends, the income in 1921 is equivalent to $8.59 per share on the common stock of $20,655,400. The 1920 dividend was $14.67.

United Dyewood Corporation—Dividends on both preferred and common stock of this corporation were announced March 1. The preferred dividend of $1.75 per share and the common of $1.50 are payable April 1 to stockholders of record March 15.

The St. Louis Market

ST. LOUIS, March 2, 1922.

The recent activity in the heavy and industrial chemical market is still apparent with evidence of a broadening demand. Prices on the whole are very steady and the general trend appears to be toward higher levels. This is especially true on goods of foreign origin, where prices are being increased solely by the rising exchange. The weak spots in the market are becoming fewer and apparently the pressure toward downward revisions has passed, and prices today are based on actual production value and replacement conditions. Increased business is also manifested by the fact that the sales for February exceeded those for the corresponding month of last year by a large margin.

ALKALIS

The alkali market remains firm with no price change since our report of Feb. 16; 76 per cent solid *caustic* is quoted at $3.40 per 100 lb. in carlots f.o.b. point of production, with 1- to 10-drum lots at $4@$4.10 delivered to buyer's door. The flake can be had at from 35 to 40c. per 100 lb. over the solid in all cases. There is no change in *soda ash*, prices still ranging from $2.40@$2.75 per 100 lb. for 58 per cent light in less than carlots. There is little doing in carlot buying. A buyers' market now prevails in *sal soda*, with a considerable range of prices.

GENERAL AND SPECIAL CHEMICALS

Producers of heavy commercial mineral acids report the market very strong, especially the *nitric acid* group, price being based on 40 deg. at $7.40 per 100 lb. f.o.b. point of production and find no difficulty in getting business. *Sulphuric acid* is also very strong. *Muriatic acid* has had an overproduction; however, the price is firm. The decline of 1c. per lb. on *boric acid* last week has given way to a better demand and there is a freer movement. The low stocks of imported *citric acid* are stimulating a demand for domestic goods. This should be an opportune time to anticipate requirements, as prices have declined to a level where further reduction would net a loss to the producer. *Carbolic acid* is moving in a fair way. There has been no change in the *gallic acid* and *pyrogallic acid* movement. While the activities in the *phosphoric acid, U.S.P. sirupy*, market have not been altogether at a standstill, the increase has not been sufficient to give prices a firmer tone, but factors believe that complete recovery will be made in a short time and that a firmer market will then exist. Producers still report a sold-up position on *white arsenic* and are quoting in carlots at 7c. St. Louis. With the continued advance in the sterling exchange, *bismuth salts* and *iodide salts* are in greater demand than ever, and producers are well situated to meet this increase.

Glycerine has eased up some, and can be had at 16c. in drums, a decline of ¼c. in last week's price. *Sulphur* has shown a little more life recently, and while the price remains constant, it has been moving in greater volume. Inquiry and demand for *zinc sulphate, U.S.P.* continue to increase, with a fair demand for the technical grade, the latter being quoted at $2.95 in carlots f.o.b. St. Louis.

Linseed oil is still firm, the raw oil price having reached 92c. last week, and is now being offered at 91c. *Castor oil* advanced ¼c. during the last few days, now being held firmly at 13¼c. in drums; in quantities of 200 gal. this price can be bettered 1c. *Turpentine* is somewhat easier, and is being offered today at 91½c. in barrels.

A very unusual condition now prevailing in the paint industry is pessimism. The paint grinders, usually optimistic, are now showing signs of losing faith, and their attitude is evident in their purchasing. One of the largest paint grinders in St. Louis recently made the statement that at the rate he was now going it would be unnecessary to purchase any more raw material this season. Prices remain unchanged and demand very poor.

The New York Market

NEW YORK, March 6, 1922.

Changes in the price levels for a number of basic commodities are the outstanding developments of the week. Although the general trend of the market is undoubtedly upward, a number of leading producers have announced lower prices for such products as bleaching powder, glycerine, and zinc sulphate. On the other hand, there have been significant increases in the case of ammonium sulphate and cottonseed oil. Prices for caustic soda have not changed appreciably among the manufacturers, but the dealers report a noticeable firmness to the market. The export inquiry for caustic has continued and a few sales of moderate volume were reported.

There was no relief seen in the nitrite of soda market. A scarcity of imported material, together with a limited amount of domestic goods on the spot market, was chiefly responsible for the present situation. Some large producers of bleaching powder have reduced prices in order to compete successfully with importers. The first-hand market, as a result, reached the lowest price since May, 1919, when sales were recorded at 1¾c. per lb. Prussiates have remained fairly firm, with odd lots in moderate demand. Zinc sulphate in carload quantities is a trifle lower.

Acetate of Soda—Some producers are not inclined to accept business in this chemical under 4¼c. per lb. It is stated that large sales have been made to the dyestuff industry on this basis. Low-priced material that was

offered so freely has been partly absorbed and offerings are much scarcer.

Barium Chloride—Higher prices have been established on spot and it is doubtful if better than $58 per ton can be done for any quantity. Some sellers quote up to $60 per ton. The demand is good, with a higher market expected in the near future.

Bichromate of Potash—Sales of small lots on spot were recorded at 10¼c. per lb. Large sellers have shaded this figure to 10¼c., while in some quarters as low as 10c. was heard. Business in only fairly moderate.

Bichromate of Soda—Trading on spot has shown no unusual activity. Dealers have sold small lots at 7¾c. per lb. Shipments are quoted at 7¼c. The call for contract deliveries is steady among leading manufacturers.

Bleaching Powder—Foreign competition is being met by domestic producers and sales have gone through at the works as low as 1¾c. per lb. Imported material has been offered at $1.80 per 100 lb. ex-dock New York. The demand is not as active as in the early part of February.

Caustic Soda—Leading producers are maintaining the contract price of 2¼c. per lb., basis 60 per cent, f.o.b. works. The demand is holding steady and shipments for the month of February have shown an increase over January. Dealers are quoting 3¼c. per lb. for March shipment.

Lead Acetate — Large factors in this commodity have announced a cent per lb. reduction on all varieties. Prices range from 9¾@12c. per lb. Business was reported a trifle better since the reduction.

Nitrite of Soda—Second hands are in possession of some limited quantities of domestic goods which are being offered at 8c. per lb. Producers are asking 8¼c. per lb., f.o.b. works. Imported material is offered sparingly, with some small-lot sales recorded at 8c. per lb. early in the week. These sellers demand 8¼c. at the close. The market is very firm.

Silicate of Soda—Large producers report sales to the consuming industries at $2.25 per 100 lb. in carload quantities for the 60 deg. Bé. Prices on the 40 deg. range from 85c. to $1.20 per 100 lb., depending on quantity.

Soda Ash—Lower prices have been established for soda ash at the works. Manufacturers offer light, 58 per cent, at $1.10 per 100 lb. in bulk, $1.20 in bags and $1.40 in barrels, basis 48 per cent, f.o.b. works. Spot and prompt shipments command a premium of 10c. per 100 lb. Dealers report sales of less than carload quantities at $1.95.

Zinc Carbonate—Producers are holding spot material at 14c. per lb. in barrels and 16c. in kegs. Moderate trading was reported at these figures.

Zinc Chloride—Domestic sales were reported by producers at 7¼c. per lb. in carlots and 8c. in smaller quantities. The demand is fair.

Zinc Sulphate—Leading factors have reduced prices in large quantities ¼c. per lb. and quote $2.75 per 100 lb. for prompt shipments. Business has improved to a noticeable extent since this reduction.

Vegetable Oils

Cottonseed Oil—The market during the past week was comparatively firm, reflecting the growing scarcity of crude material. New high figures were established at the close of trading. All short interests in the market were virtually liquidated. Winter oil on spot for domestic consumption was held around 13¼@13¼c. per lb. Crude cottonseed sold at a new high mark, sales passing at 10¼@10¼c. per lb., buyers' tanks, f.o.b. mills.

Linseed Oil—The market was easier, with fairly liberal offerings of imported material in several directions.

Fertilizers

Ammonium Sulphate—The market on this product has become one of the outstanding features in the chemical market. Spot supplies have practically disappeared and futures have been offered in only a very limited way. The export inquiry has become more active and unfilled orders for large quantities have been on the market for the past weeks. Material in double bags, f.a.s. N. Y., was quoted at 3c. per lb. Goods at the works are nominal, with a stray offering heard now and then at 2¾c. per lb.

The Iron and Steel Market

PITTSBURGH, March 3, 1922.

There has been a slight further increase in steel mill operations, the rate of steel ingot production at present being set at 29,000,000 tons a year, against 28,000,000 tons a fortnight ago, less than 18,000,000 tons at the end of December, and 23,000,000 tons last October and November, the highest rate since February a year ago.

Latest reports, not generally circulated as yet, are that there has been a noticeable falling off in buying of important finished steel products in the past week or 10 days. This might be regarded as quite natural in the circumstances, but the period of observation is too short to justify definite conclusions. A period of 30 days would be better.

The buying of steel has been widespread in character and is thoroughly healthy in that respect. There is even a fair percentage of railroad business, fully as much as could be expected in present railroad conditions. Even the agricultural implement trade, long the slackest of all the steel consumers, has been doing a little business. Demand for steel for the building trades is good rather than merely fair, seen particularly in standard steel pipe, both black and galvanized, and in sheets for metal lath, ceiling, eaves trough and conductor pipe, etc. The automobile trade is taking a natural proportion.

More Price Weakness

Some fresh price weakness has developed, although only in certain lines. Bars, shapes and plates, which got to an unexpectedly low level when they reached 1.40c. recently, are by no means rallying around that price, as in the Pittsburgh district lower prices have been made on certain large orders, while east and west the divergences from Pittsburgh basing have been more pronounced, the probability being that approximately 1.40c. f.o.b. mill has been done, representing very much less than 1.40c. f.o.b. Pittsburgh. In tubular goods the concessions from the regular lists have grown rather sharply in the past week or two, so much so that there is question whether new lists will not have to be issued.

In sheets the prices established more than 3 months ago, 2.25c. for blue annealed, 3c. for black and 4c. for galvanized, are still maintained, but this price steadiness, instead of being regarded as a support or stimulus to the steel market in general, is now regarded rather as an anomaly. The sheet prices present the curious phenomenon of affording a slight profit to the producers. Tinplate is in this category also, but that is not phenomenal, since tin plate is different from all other steel commodities and is promised a full demand for this year if not indeed a record demand.

The market in wire products is perhaps a trifle steadier. The special price of $2.40 on nails, as against the regular or official price of $2.50, has now become practically general, but on the other hand plain wire, instead of yielding correspondingly, seems to be steady at its regular price of 2.25c.

Pig Iron

Recent sales of basic pig iron on the basis of $17.75 valley are now regarded as making the market rather than as being exceptional and $18 is considered merely an asking price. Bessemer has sold in carload lots in the past week at its old price of $19.50, although there is little doubt that the $19 basis, done recently on a fair-sized lot, would apply on any tonnage. Foundry iron has sold more often at $19 valley than at $18.75.

Connellsville furnace coke has no more than held its recent advance to a range of $3.25@$3.50. Demand for coal, an important factor in coke prices, has decreased in the past 10 days, and the expectation that Connellsville operators could do better in the coal market than in the coke market is not yet justified. Foundry coke, however, has gone up some more, being now quotable strong at $4.25@$4.75, depending on brand, representing a straight advance of 50c. in 2 or 3 weeks.

The Pittsburgh Steel Co. and the Jones & Laughlin Steel Co., long absent from the scrap market, have in the past few days bought more than 10,000 tons of heavy melting steel, the reported price being $15. Dealers had been bidding $14 @$14.50 for odd lots as they appeared.

General Chemicals

CURRENT WHOLESALE PRICES IN NEW YORK MARKET

		Carlots	Less Carlots
Acetic anhydride	lb.	... – ...	$0.40 – $0.42
Acetone	lb.	$0.12½– $0.12¾	.13 – .13½
Acid, acetic, 28 per cent	100 lbs.	2.50 – 2.60	2.65 – 3.00
Acetic, 56 per cent	100 lbs.	5.00 – 5.25	5.30 – 5.50
Acetic, glacial, 99½ per cent, carboys,	100 lbs.	9.00 – 9.50	9.75 – 10.00
Boric, crystals	lb.	.11 – .11½	.11½– .12
Boric, powder	lb.	.11½– .11¾	.11¾– .12½
Citric	lb.	... – ...	.44½– .45
Hydrochloric	100 lb.	1.15 – 1.25	1.30 – 1.75
Hydrofluoric, 52 per cent	lb.	.11 – .11½	.11½– .12
Lactic, 44 per cent tech	lb.	.09½– .10	.10½– .12
Lactic, 22 per cent tech	lb.	.04 – .04½	.04½– .05
Molybdic, c.p.	lb.	3.00 – 3.25	3.30 – 3.75
Muriatic, 20 deg. (see hydrochloric)	....	... – ...	... – ...
Nitric, 40 deg.	lb.	.06½– .06¾	.06¾– .07
Nitric, 42 deg.	lb.	.06¾– .07	.07¼– .07¾
Oxalic, crystals	lb.	.12 – .12½	.13 – .14
Phosphoric, 50 per cent solution	lb.	.08 – .08½	.08½– .09½
Picric	lb.	.20 – .25	.27 – .35
Pyrogallic, resublimed	lb.	... – ...	1.65 – 1.75
Sulphuric, 60 deg., tank cars	ton	10.00 – 11.00	..... – .....
Sulphuric, 60 deg., drums	ton	12.00 – 14.00	..... – .....
Sulphuric, 66 deg., tank cars	ton	16.00 – 16.50	..... – .....
Sulphuric, 66 deg., drums	ton	20.00 – 20.50	21.00 – 22.00
Sulphuric, 66 deg., carboys	ton	..... –	..... – .....
Sulphuric, fuming, 20 per cent (oleum) tank cars	ton	19.50 – 20.00	..... – .....
Sulphuric, fuming, 20 per cent (oleum) drums	ton	22.00 – 22.50	23.00 – 24.00
Sulphuric, fuming, 20 per cent (oleum) carboys	ton	31.00 – 32.00	33.00 – 34.00
Tannic, U. S. P.	lb.	... – ...	.60 – .75
Tannic (tech.)	lb.	.40 – .45	.46 – .50
Tartaric, imported crystals	lb.	..... –	.25 – .26
Tartaric acid, imported, powdered	lb.	..... –	.26 – .29
Tartaric acid, domestic	lb.	..... –	... – .30
Tungstic, per lb. of WO	lb.	..... –	1.00 – 1.10
Alcohol, ethyl	gal.	..... –	4.75 – 5.50
Alcohol, methyl (see methanol)	....	... – ...	... – ...
Alcohol, denatured, 188 proof No. 1	gal.	..... –	.36 – .37
Alcohol, denatured, 188 proof No. 5	gal.	..... –	.36 – .37
Alum, ammonia, lump	lb.	.03½– .03¾	.04 – .04½
Alum, potash, lump	lb.	.03½– .03¾	.03¾– .05
Alum, chrome lump	lb.	.07½– .08	.08½– .08¾
Aluminum sulphate, commercial	100 lb.	1.65 – 1.85	1.90 – 2.40
Aluminum sulphate, iron free	lb.	.02½– .02¾	.03 – .03½
Aqua ammonia, 26 deg., drums (750 lb.)	lb.	.07½– .07¾	.08 – .08½
Ammonia, anhydrous, cyl. (100-150 lb.)	lb.	.30 – .30½	.31 – .33
Ammonium carbonate, powder	lb.	.07 – .07½	.08 – .09
Ammonium nitrate	lb.	.06½– .07	.07¼– .07½
Amylacetate tech.	gal.	... – ...	2.00 – 2.40
Arsenic, white, powdered	lb.	.07 – .07½	.07½– .08
Arsenic, red, powdered	lb.	.12 – .12½	.12½– .13
Barium chloride	ton	58.00 – 60.00	61.00 – 70.00
Barium dioxide (peroxide)	lb.	.20 – .21	.21½– .22
Barium nitrate	lb.	.06½– .07	.07¼– .08½
Barium sulphate (precip.) (blanc fixe)	lb.	.03½– .04	.04¼– .04½
Blanc fixe, dry	lb.	.04 – .04½	... – ...
Blanc fixe, pulp	ton	45.00 – 55.00	... – ...
Bleaching powder	100 lb.	1.75 – 2.00	2.05 – 3.00
Blue vitriol (see copper sulphate)	....	... – ...	... – ...
Borax	lb.	.05¼– .05¾	.06 – .06½
Brimstone (see sulphur, roll)	....	... – ...	... – ...
Bromine	lb.	.20 – .21	.21½– .26
Calcium acetate	100 lbs.	1.75 – 2.00	... – ...
Calcium carbide	lb.	.04½– .04¾	.05 – .05½
Calcium chloride, fused, lump	ton	24.00 – 24.50	24.75 – 27.00
Calcium chloride, granulated	lb.	.01¾– .02	.02¼– .02½
Calcium peroxide	lb.	..... –	1.40 – 1.50
Calcium phosphate, tribasic	lb.	..... –	.15 – .16
Camphor	lb.	..... –	.90 – .92
Carbon bisulphide	lb.	.06 – .06½	.06¾– .07½
Carbon tetrachloride, drums	lb.	.10½– .10¾	.11 – .12
Carbonyl chloride, (phosgene)	lb.	..... –	.60 – .75
Caustic potash (see potassium hydroxide)	....	... – ...	... – ...
Caustic soda (see sodium hydroxide)	....	... – ...	... – ...
Chalk, precip.—domestic, light	lb.	.04½– .04¾	..... – .....
Chalk, precip.—domestic, heavy	lb.	.03½– .03¾	..... – .....
Chalk, precip.—imported, light	lb.	.04½– .05	... – ...
Chlorine, gas, liquid-cylinders (100 lb.)	lb.	.06 – .06½	.06½– .07
Chloroform	lb.	..... –	.37 – .40
Cobalt oxide	lb.	..... –	2.00 – 2.10
Copperas	ton	15.00 – 16.00	16.50 – 30.00
Copper carbonate, green precipitate	lb.	.19 – .20	.20½– .21
Copper cyanide	lb.	... – ...	.58 – .60
Copper sulphate, crystals	100 lb.	5.55 – 5.65	5.70 – 6.25
Cream of tartar	lb.	..... –	.24 – .25
Epsom salt (see magnesium sulphate)	....	... – ...	... – ...
Ethyl acetate com. 85%	gal.	..... –	.60 – .65
Ethyl acetate, pure (acetic ether, 98% to 100%)	gal.	... – ...	.93 – 1.00
Formaldehyde, 40 per cent	lb.	.09 – .9½	.09½– .10½
Fullers earth, f.o.b. mines	net ton	16.00 – 17.00	... – ...
Fullers earth—imported powdered—net	ton	30.00 – 32.00	... – ...
Fusel oil, ref.	gal.	... – ...	2.50 – 3.00
Fusel oil, crude	gal.	..... –	1.40 – 1.75
Glauber's salt (see sodium sulphate)	....	... – ...	... – ...
Glycerine, c. p. drums extra	lb.	..... –	.16 – .17
Iodine, resublimed	lb.	..... –	4.05 – 4.15
Iron oxide, red	lb.	..... –	.12 – .18
Lead acetate	lb.	..... –	.10 – .12
Lead arsenate, powd.	lb.	.15 – .15½	.15½– .16½
Lead nitrate	lb.	..... –	.15 – .20
Litharge	lb.	.07½– .07¾	.08 – .08½
Magnesium carbonate, technical	lb.	.06 – .06½	.06½– .08
Magnesium sulphate, U. S. P.	100 lb.	2.65 – 2.70	2.75 – 3.00
Magnesium sulphate, technical	100 lb.	..... –	1.00 – 1.80
Methanol, 95%	gal.	..... –	.57 – .58
Methanol, 97%	gal.	..... –	.59 – .60
Nickel salt, double	lb.	..... –	.11 – .11½
Nickel salt, single	lb.	..... –	.11 – .11½
Phosgene (see carbonyl chloride)	....	... – ...	... – ...
Phosphorus, red	lb.	.45 – .46	.47 – .50
Phosphorus, yellow	lb.	.... –	.30 – .35

		Carlots	Less Carlots
Potassium bichromate	lb.	.10¼– .10½	.10½– .10¾
Potassium bromide, granular	lb.	... – ...	.13 – .17
Potassium carbonate, U. S. P.	lb.	.12 – .12½	.13 – .16
Potassium carbonate, 80–85%	lb.	.04 – .04½	.04¼– .05½
Potassium chlorate, crystals	lb.	.05½– .06	.06½– .08
Potassium cyanide	lb.	... – ...	.42 – .45
Potassium hydroxide (caustic potash)	100 lb.	5.65 – 5.75	5.80 – 6.50
Potassium iodide	lb.	... – ...	3.10 – 3.15
Potassium nitrate	lb.	.07½– .07¾	.08 – .09
Potassium permanganate	lb.	.13 – .14	.14½– .22
Potassium prussiate, red	lb.	nominal	nominal
Potassium prussiate, yellow	lb.	.25½– .26	.26½– .26¾
Rochelle salts (see sodium potas. tartrate)	....	... – ...	... – ...
Salammoniac, white, granular	lb.	.06¾– .07	.07½– .07¾
Salammoniac, gray, granular	lb.	.06¼– .06¾	.07 – .07½
Salsoda	100 lb.	1.60 – 1.70	1.75 – 2.00
Salt cake (bulk)	ton	17.00 –20.00	... – ...
Soda ash, light	100 lb.	1.80 – 1.90	1.95 – 2.40
Soda ash, dense	100 lb.	1.85 – 1.95	2.00 – 2.50
Sodium acetate	lb.	.04¼– .04½	.04¾– .05
Sodium bicarbonate	100 lb.	2.10 – 2.15	2.20 – 2.50
Sodium bichromate	lb.	.07¾– .08	.08¼– .08½
Sodium bisulphate (nitre cake)	ton	4.50 – 4.60	4.65 – 5.50
Sodium bisulphite powdered, U.S.P.	lb.	.04¾– .04¼	.04¾– .05¼
Sodium chlorate	lb.	.06¾– .06¾	.07 – .07½
Sodium chloride	long ton	12.00 –13.00	... – ...
Sodium cyanide	lb.	.22½– .26	.26½– .27½
Sodium fluoride	lb.	.09½– .10	.10½– .11
Sodium hydroxide (caustic soda)	100 lb.	3.45 – 3.50	3.55 – 4.00
Sodium hyposulphite	lb.	.03½– .03½	.03½– .04
Sodium nitrite	lb.	.08 – .08½	.08½– .08¾
Sodium peroxide, powdered	lb.	.28 – .30	.31 – .35
Sodium phosphate, dibasic	lb.	.03½– .04	.04¼– .04½
Sodium potassium tartrate (Rochelle salts)	lb.	... – ...	.18 – .21
Sodium prussiate, yellow	lb.	.18½– .18½	.18½– .19
Sodium silicate, solution (40 deg.)	100 lb.	.85 – 1.00	1.05 – 1.15
Sodium silicate, solution (60 deg.)	100 lb.	2.50 – 2.60	2.65 – 3.00
Sodium sulphate, crystals (glaubers salt)	100 lbs.	1.15 – 1.25	1.30 – 1.90
Sodium sulphide, fused, 60-62 per cent (conc.)	lb.	.04¾– .04½	.04¾– .05
Sodium sulphite, crystals	lb.	.03½– .03¾	.03½– .04½
Strontium nitrate, powdered	lb.	.10 – .11	.11½– .15
Sulphur chloride, red	lb.	.05 – .05½	.05½– .06
Sulphur, crude	ton	18.00 –20.00	..... – .....
Sulphur dioxide, liquid, cylinders extra	lb.	.08 – .08½	.09 – .10
Sulphur (sublimed), flour	100 lb.	..... –	2.25 – 3.10
Sulphur, roll (brimstone)	100 lb.	..... –	2.00 – 2.75
Talc—imported	ton	30.00 –40.00	... – ...
Talc—domestic powdered	ton	18.00 –25.00	... – ...
Tin bichloride	lb.	.09 – .09½	.09½– .10
Tin oxide	lb.	... – ...	.39 – .40
Zinc carbonate	lb.	.14 – .14½	.14¾– .15½
Zinc chloride, gran.	lb.	.07½– .08	.08¼– .08½
Zinc cyanide	lb.	.42 – .44	.45 – .47
Zinc oxide, XX	lb.	.07½– .08	.08½– .08¾
Zinc sulphate	100 lb.	2.75 – 3.00	3.05 – 3.30

Coal-Tar Products

NOTE—The following prices are for original packages in large quantities:

Alpha-naphthol, crude	lb.	$1.00 — $1.05
Alpha-naphthol, refined	lb.	1.10 — 1.15
Alpha-naphthylamine	lb.	.29 — .30
Aniline oil, drums extra	lb.	.16½— .17
Aniline salts	lb.	.24 — .26
Anthracene, 80% in drums (100 lb.)	lb.	.75 — 1.00
Benzaldehyde U.S.P.	lb.	1.25 — 1.30
Benzidine, base	lb.	.85 — .95
Benzidine sulphate	lb.	.75 — .85
Benzoic acid, U.S.P.	lb.	.60 — .65
Benzoate of soda, U.S.P.	lb.	.55 — .57
Benzene, pure, water-white, in drums (100 gal.)	gal.	.29 — .35
Benzene, 90%, in drums (100 gal.)	gal.	.27 — .32
Benzyl chloride, 95-97%, refined	lb.	.25 — .27
Benzyl chloride, tech.	lb.	.20 — .23
Beta-naphthol benzoate	lb.	3.75 — 4.00
Beta-naphthol, sublimed	lb.	.60 — .65
Beta-naphthol, tech	lb.	.27 — .30
Beta-naphthyla mine, sublimed	lb.	1.50 — 1.60
Cresol, U. S. P., in drums (100 lb.)	lb.	.15 — .16
Ortho-cresol, in drums (100 lb.)	lb.	.18 — .20
Cresylic acid, 97–99%, straw color, in drums	gal.	.50 — .52
Cresylic acid, 95-97%, dark, in drums	gal.	.45 — .47
Dichlorbenzene	lb.	.06 — .09
Diethylaniline	lb.	1.10 — 1.15
Dimethylaniline	lb.	.38 — .40
Dinitrobenzene	lb.	.22 — .25
Dinitroclorbenzene	lb.	.23 — .25
Dinitronaphthalene	lb.	.32 — .35
Dinitrophenol	lb.	.35 — .38
Dinitrotoluene	lb.	.22 — .24
Dip oil, 25%, car lots, in drums	gal.	.24 — .26
Diphenylamine	lb.	.59 — .70
H-acid	lb.	.90 — 1.00
Meta-phenylenediamine	lb.	.95 — 1.00
Monochlorbenzene	lb.	.12 — .15
Monoethylaniline	lb.	1.20 — 1.25
Naphthalene crushed, in bbls.	lb.	.06½— .07
Naphthalene, flake	lb.	.06½— .07½
Naphthalene, balls	lb.	.07½— .08½
Naphthionic acid, crude	lb.	.65 — .70
Nitrobenzene	lb.	.10 — .12
Nitro-naphthalene	lb.	.30 — .35
Nitro-toluene	lb.	.15 — .17½
Ortho-amidophenol	lb.	2.75 — 2.80
Ortho-dichlor-benzene	lb.	.15 — .20
Ortho-nitro-phenol	lb.	.75 — .80
Ortho-nitro-toluene	lb.	.15 — .20
Ortho-toluidine	lb.	.20 — .25
Para-amidophenol, base	lb.	1.25 — 1.30
Para-amidophenol, HCl	lb.	1.30 — 1.35
Para-dichlorbenzene	lb.	.15 — .18
Paranitroaniline	lb.	.75 — .77
Para-nitrotoluene	lb.	.70 — .75
Para-phenylenediamine	lb.	1.50 — 1.55
Para-toluidine	lb.	1.10 — 1.15
Phthalic anhydride	lb.	.35 — .38

Phenol, U. S. P., drums	lb.	.11½ —	.15
Pyridine	gal.	1.75 —	2.75
Resorcinol, technical	lb.	1.25 —	1.30
Resorcinol, pure	lb.	1.80 —	1.95
Salicylic acid, tech., in bbls.	lb.	.18 —	.20
Salicylic acid, U. S. P.	lb.	.22 —	.23
Salol	lb.	.80 —	.82
Solvent naphtha, water-white, in drums, 100 gal.	gal.	.25 —	.28
Solvent naphtha, crude, heavy, in drums, 100 gal.	gal.	.12 —	.14
Sulphanilic acid, crude	lb.	.25 —	.27
Toluidine	lb.	1.20 —	1.30
Toluidine, mixed	lb.	.32 —	.38
Toluene, in tank cars	gal.	.25 —	.28
Toluene, in drums	gal.	.30 —	.35
Xylidines, drums, 100 gal.	lb.	.40 —	.45
Xylene, pure, in drums	gal.	.40 —	.45
Xylene, pure, in tank cars	gal.	.45 —	....
Xylene, commercial, in drums, 100 gal.	gal.	.33 —	.35
Xylene, commercial, in tank cars	gal.	.30 —	....

Waxes

Candelilla Wax.....25-26c. per lb.
Carnauba Wax—No. 3—North Country....15½-16c. per lb.

All other prices remain quotably unchanged.

Naval Stores

All prices are f.o.b. New York unless otherwise stated, and are based on carload lots. The oils in 50-gal. bbls., gross weight, 500 lb.

Rosin B-D, bbl	280 lb.	$5.30 —	5.35
Rosin E-I	280 lb.	5.40 —	5.45
Rosin K-N	280 lb.	6.05 —	6.80
Rosin W. G.-W. W	280 lb.	7.00 —	7.25
Wood resin, bbl	280 lb.	6.25 —	.....
Spirits of turpentine	gal.	.85 —	.....
Wood turpentine, steam dist.	gal.	.83 —	.....
Wood turpentine, dest. dist.	gal.	.82 —	.....
Pine tar pitch, bbl	200 lb.	..... —	6.00
Tar, kiln burned, bbl. (500 lb.)	bbl.	..... —	10.00
Retort tar, bbl	500 lb.	—	9.00
Rosin oil, first run	gal.	.36 —	.....
Rosin oil, second run	gal.	.39 —	.....
Rosin oil, third run	gal.	.46 —	.....
Pine oil, steam dist., sp.gr., 0.930-0.940	gal.		$1.90
Pine oil, pure, dest. dist.	gal.		1.50
Pine tar oil, ref., sp.gr. 1.025-1.035	gal.		.46
Pine tar oil, crude, sp.gr. 1.025-1.035 tank cars f.o.b. Jacksonville, Fla.	gal.		.35
Pine tar oil, double ref., sp.gr. 0.965-0.990	gal.		.75
Pine tar, ref., thin, sp.gr., 1.080-1.960	gal.		.35
Turpentine, crude, sp. gr., 0.900-0.970	gal.		1.25
Hardwood oil, f.o.b. Mich., sp.gr., 0.960-0.990	gal.		.35
Pinewood creosote, ref	gal.		.52

Fertilizers

Ammonium sulphate, bulk	100 lb.	$2.85 —	3.00
Blood, dried, f.o.b., N. Y	unit	4.00	
Bone, 3 and 50, ground, raw	ton	30.00 —	32.00
Fish scrap, dom., dried, f.o.b. works	unit	3.10 —	3.20
Nitrate soda	100 lb	2.45 —	2.50
Tankage, high grade, f.o.b. Chicago	unit	3.25 —	3.40
Phosphate rock, f.o.b. mines, Florida pebble, 68-72%	ton	5.50 —	7.00
Tennessee, 78-80%	ton	8.50 —	9.00
Potassium muriate, 80%	ton	34.00 —	37.00
Potassium sulphate	unit	1.00 —	.....

Crude Rubber

Prices remain the same as March 1st report.

Oils

VEGETABLE

The following prices are f.o.b. New York for carload lots.

Castor oil, No. 3, in bbls	lb.	$0.10 —	$0.10½
Castor oil, AA, in bbls	lb.	.11½ —	.12
China wood oil, in bbls	lb.	.14 —	.14½
Cocoanut oil, Ceylon grade, in bbls	lb.	.09 —	.09½
Cocoanut oil, Cochin grade, in bbls	lb.	.09½ —	.10
Corn oil, crude, in bbls	lb.	.10½ —	.10¾
Cottonseed oil, crude (f. o. b. mill)	lb.	.10½ —	.10¾
Cottonseed oil, summer yellow	lb.	.11¼ —	.11¾
Cottonseed oil, winter yellow	lb.	.13¼ —	.13¾
Linseed oil, raw, car lots (domestic)	gal.	.85 —	.86
Linseed oil, raw, tank cars (domestic)	gal.	.81 —	.82
Linseed oil, in 5-bbl lots (domestic)	gal.	.89 —	.90
Olive oil, denatured	gal.	1.15 —	1.20
Palm, Lagos	lb.	.08½ —	.08¾
Palm, Niger	lb.	.06½ —	.06¾
Peanut oil, crude, tank cars (f.o.b. mill)	lb.	.10 —	.10½
Peanut oil, refined, in bbls	lb.	.13 —	.13½
Rapeseed oil, refined in bbls	gal.	.86 —	.87
Rapeseed oil, blown, in bbls	gal.	.88 —	.89
Soya bean oil (Manchurian), in bbls. N. Y.	lb.	.10½ —	....
Soya bean oil, tank cars, f.o.b., Pacific coast	lb.	nominal	

FISH

Light pressed menhaden	gal.	$0.53 —	....
Yellow bleached menhaden	gal.	.56 —	....
White bleached menhaden	gal.	.55 —	....
Blown menhaden	gal.	.60 —	....

Miscellaneous Materials

All f.o.b. New York Unless Otherwise Stated

Asbestos, crude No. 1, f.o.b., Quebec, Canada	short ton	$800.00	$1,000.00
Asbestos, shingle stock, f.o.b., Quebec, Canada	short ton	70.00 —	120.00
Asbestos, cement stock, f.o.b., Quebec, Canada	short ton	12.50 —	17.50
Barytes, ground, white, f.o.b. mills	net ton	23.00 —	23.50
Barytes, ground, off color f.o.b. mills	net ton	17.00 —	21.50
Barytes, floated, f.o.b. St. Louis	net ton	23.00 —	24.00
Barytes, crude f.o.b. mines	net ton	6.00 —	7.00
Casein	lb.	.11 —	.12

All other prices remain unchanged.

Refractories

Quotations the same as previous report.

Ferro-Alloys

All f.o.b. Works

Ferrocarbon-titanium, 15-18%, f.o.b. Niagara Falls, N. Y	net ton	$200.00 —	$225.00
Ferrochromium, per lb. of Cr contained, 6-8% carbon, carlots	lb.	.11½ —	....
Ferrochromium, per lb. of Cr contained, 4-6% carbon, carlots	lb.	.12 —	....
Ferromanganese, 76-80% Mn, domestic	gross ton	59.00 —	60.00
Ferromanganese, 78-82% Mn, English and German c. i.f. Atlantic seaport	gross ton	58.00 —	62.50
Spiegeleisen, 18-22% Mn	gross ton	30.00 —	32.00
Ferromolybdenum, 50-60% Mo, per lb. of Mo	lb.	2.25 —	....
Ferrosilicon, 10-15%	gross ton	38.00 —	40.00
Ferrosilicon, 50%	gross ton	54.00 —	55.00
Ferrosilicon, 75%	gross ton	115.00 —	120.00
Ferrotungsten, 70-80%, per lb. of contained W	lb.	.37 —	.50
Ferro-uranium, 35-50% of U, per lb. of U content	lb.	6.00 —	.....
Ferrovanadium, 30-40% per lb. of contained V.	lb.	4.00 —	4.25

Ores and Semi-finished Products

All f.o.b. New York, Unless Otherwise Stated

Bauxite, 52% Al content	net ton	$6.00 —	$12.00
Chrome ore, Calif. concentrates, 50% min. Cr_2O_3	ton	21.00 —	22.00
Chrome ore, 50% Cr_2O_3, f.o.b. Atlantic seaboard	ton	20.00 —	21.00
Coke, foundry, f.o.b. ovens	net ton	4.00 —	4.25
Coke, furnace, f.o.b. ovens	net ton	3.25 —	3.50
Fluorspar, gravel, f.o.b. mines, New Mexico	net ton	12.00 —	.....
Fluorspar, standard, domestic washed gravel Kentucky and Illinois mines	net ton	20.00 —	22.00
Ilmenite, 52% TiO_2, per lb. ore	lb.	.01½ —	.01¾
Manganese ore, 50% Mn, c.i.f. Atlantic seaport	unit	.23 —	.25
Manganese ore, chemical (MnO_2)	net ton	55.00 —	60.00
Molybdenite, 85% MoS_2, per lb. of MoS_2, N. Y.	lb.	.48 —	.50
Monazite, per unit of ThO_2, c.i.f., Atlantic seaport	unit	27.00 —	.....
Pyrites, Spanish, fines, c.i.f., Atlantic seaport	unit	.12 —	.12
Pyrites, Spanish, furnace size, c.i.f. Atlantic seaport	unit	.13 —	.13
Pyrites, domestic, fines, f.o.b. mines, Ga.	unit	.11 —	.12
Rutile, 95% TiO_2 per lb. ore	lb.	.12 —	.....
Tungsten, scheelite, 60% WO_3 and over, per unit of WO_3 (nominal)	unit	2.25 —	2.50
Tungsten, wolframite, 60% WO_3 and over, per unit of WO_3, N. Y. C.	unit	2.50 —	2.75
Uranium ore (carnotite) per lb. of U_3O_8	lb.	1.25 —	1.75
Uranium oxide, 96% per lb. contained U_3O_8	lb.	2.25 —	2.50
Vanadium pentoxide, 99%	lb.	12.00 —	14.00
Vanadium ore, per lb. of V_2O_5 contained	lb.	1.00 —	.....
Zircon, washed, iron free, f.o.b. Pablo, Florida	lb.	.04½ —	.13½

Non-Ferrous Metals

New York Markets

	Cents per Lb.
Copper, electrolytic	12.75
Aluminum, 98 to 99 per cent	19.00
Antimony, wholesale lots, Chinese and Japanese	4.35
Nickel, ordinary (ingot)	41.00
Nickel, electrolytic	44.00
Nickel, electrolytic, resale	32.00
Monel metal, shot and blocks	35.00
Monel metal, ingots	38.00
Monel metal, sheet bars	40.00
Tin, 5-ton lots, Straits	29.50
Lead, New York, spot	4.70
Lead, E. St. Louis, spot	4.40
Zinc, spot, New York	4.95–5.00
Zinc, spot, E. St. Louis	4.50–4.55

OTHER METALS

Silver (commercial)	oz.	$0.64½
Cadmium	lb.	1.00–1.10
Bismuth (500 lb. lots)	lb.	1.90@2.00
Cobalt	lb.	3.00@3.25
Magnesium (f.o.b. Philadelphia)	lb.	1.25
Platinum	oz.	85.00@ 90.00
Iridium	oz.	170.00@190.00
Palladium	oz.	55.00@ 60.00
Mercury.....75	lb.	49.50

Industrial

Financial, Construction and Manufacturers' News

Construction and Operation

Alabama

ROBERSTDALE — The Sanford-Seever Orchard Co. is planning for the construction of a new gas-producer plant at its properties.

DOTHAN—Fire, Feb. 14, destroyed a portion of the refining plant of the Dothan Syrup Co., with loss estimated at about $75,000, including equipment.

Arizona

JEROME—The United Verde Copper Co. is completing plans for the construction of a new crushing plant at Clarkdale, Ariz., estimated to cost about $1,500,000, with machinery. Contract for foundation work has been let to Twohy Bros., Phœnix, Ariz., at a cost of approximately $150,000.

California

BURBANK—The American Aluminum-Metal Products Co. has awarded a contract to R. W. McCrea, Huntington Park, Cal., for the erection of its proposed new local plant, comprising a group of seven buildings, estimated to cost in excess of $90,000. Richard D. King, 519 Van Nuys Bldg., Los Angeles, is architect.

Florida

CHULUOTA—The Petrous Mfg. Co., recently organized with a capital of $50,000, is planning for the erection of a 2-story plant, 40 x 85 ft., for the manufacture of cement brick and kindred products. The works will be equipped for an initial daily output of 30,000 bricks. Frank Wheeler is president; J. A. Rogers is secretary and treasurer in charge.

FORT PIERCE—The Gulf Sugar Corp. has completed plans and will soon commence the erection of a new sugar refinery on local site, with initial capacity of about 100 tons per day.

SEABREEZE—The Town Council has plans under way for the installation of a water-softening plant in connection with extensions and improvements to the waterworks system.

Georgia

ATLANTA—The White Provision Co. is planning for the erection of a new fertilizer works at its plant. The capacity of the lard refinery will be increased with the installation of new equipment. The company will also build a new electric power plant. The capital has recently been increased to $1,000,000 for expansion. W. H. White, Jr., is president.

Illinois

BRISHENE—The Western Union Telegraph Co., Van Buren near Scott St., Joliet, Ill., has plans under way for the erection of a new creosoting plant for pole treatment at Frankfort, near Brishene, estimated to cost about $60,000, including equipment.

Indiana

BLOOMINGTON—The Bloomington Brick & Tile Co. has plans nearing completion for the construction of a new plant at Unionville, near Bloomington, for the manufacture of brick, tile and other burned clay products, estimated to cost about $250,000, including machinery. The company is arranging for the financing of the project. A. W. Beecher is president.

Kentucky

CATLETTSBURG—The Great Eastern Refining Co., recently organized with a capital of $200,000, A. J. Dalton, Huntington, W. Va., president, is planning for the erection of a new oil-refining plant at Leach, near Catlettsburg, with initial capacity of about 500 bbl. A site has been selected and work will be commenced at an early date. The equipment installation will include agitators, stills, tanks, and general operating machinery. T. H. Gilman is general manager.

Maryland

BALTIMORE—The Standard Oil Co., Pratt and Commercial Sts., has completed plans for the construction of a 2-story chemical mixing and pumping plant on Third Ave., near Second St.

TEXAS—The J. B. Logan Lime Co. will install a new 30-in. grinding mill at its plant.

BALTIMORE—The Pompeian Romanza Corp., recently organized with a capital of $1,760,000, has acquired the plant, property and equipment of Musher & Co., manufacturer of olive oil products, at Fayette and 11th Sts., for a consideration said to be $600,000. The new owner will use the plant for the manufacture of edible oils, compounds, etc., and will commence operations at an early date. It is headed by W. W. and W. H. Cook, and W. H. Hamilton.

Massachusetts

MALDEN—The Silex Co. of Massachusetts has acquired the factory of the Franklin Rubber Co., 926 Eastern Ave., for the operation of a plant for the manufacture of glass products.

FALL RIVER—The Atlantic Refining Co., 3144 Passyunk Ave., Philadelphia, manufacturer of refined oil products, is planning for the erection of a new plant at the foot of Slade St., Fall River, estimated to cost close to $1,000,000, including equipment. Metzger & Fisher, Otis Bldg., Philadelphia, are contractors for certain features of the project.

Michigan

CADILLAC—The new plant of the Cadillac Lumber & Chemical Co., to be located at Sault Ste. Marie, Mich., will consist of a number of buildings, estimated to cost in excess of $150,000, including machinery. The plant will have a department for the production of acetate of lime, with capacity of about 2 cars a week; for the manufacture of wood alcohol, charcoal and other affiliated products. Work will be commenced early in the spring, and will be pushed to completion. It is expected to give employment to more than 400 persons. The present plant will be removed to this location. The company is operating with a capital of $1,000,000.

IONA—The Michigan Porcelain Tile Co. has completed plans and will take bids at once for the erection of a new 1-story and basement plant, 120 x 155 ft., estimated to cost about $42,000. P. Lindout, 5th floor, Michigan Trust Bldg., Grand Rapids, is architect. H. Kidder is general manager.

Missouri

ST. CHARLES—The Weldon Spring Quarry, recently organized, is planning for the establishment of a lime-fertilizer plant, in connection with its quarry properties in this section, with a daily capacity of about 2 carloads of material. A rock-crushing plant will be installed with daily output of about 6 carloads of crushed material.

KANSAS CITY—The Lion Oil & Refining Co. is planning for the installation of new equipment at its plant, including agitator, tanks, etc. The company will construct a new pipe line to cost about $80,000. Victor H. Smith is general manager.

New Jersey

NEWARK—The United Butchers' Fat & Reducing Co., Doremus Ave., has filed plans for the erection of its proposed new plant, consisting of a main factory to cost about $23,000, power house, garage and other operating buildings. The plant will be used for the manufacture of soaps, greases, etc.

PERTH AMBOY—Fire, Feb. 23, destroyed a portion of the chemical plant of the Novo Laboratories, 651 Catherine St., with loss estimated at about $15,000.

New York

NEW YORK—The New Amsterdam Gas Co., 130 East 15th St., has filed plans for the construction of a new laboratory and switch house, 63 x 107 ft., at its plant at 403-7 East 40th St., to cost about $100,000. William Whitehill, Buckley-Newhall Bldg., 6th Ave and 41st St., is architect and engineer.

NEW YORK—Fire, Feb. 21, damaged a portion of the plant of the Redding Chemical Works, Inc., 329 East 47th St., manufacturer of printing and lithographing inks. An official estimate of the loss has not been announced.

Oklahoma

SAYRE—The Common Council will install a new filtration plant in connection with extensions and improvements in the waterworks system.

MADILL—The Common Council is planning for the construction of a filtration plant and other improvements at the municipal waterworks to cost about $500,000.

Pennsylvania

LOCK HAVEN—The American Aniline Products Co. is planning for the erection of a 2-story and basement plant building, 200 x 250 ft., to replace the factory recently destroyed by fire with loss of about $150,000. The new structure will cost a like amount. Headquarters of the company are at 80 5th Ave., New York, N. Y.

FAIRCHANCE—The Quertinmont Glass Co., manufacturer of window glass, has preliminary plans under way for the erection of a new plant at Fairchance, to be of "five-pot" initial capacity, giving employment to more than 500 operatives. A new process of glass manufacture will be used. It is expected to have the plant ready for operation in the fall, with additional plant units to be built in 1923. Jules J. Quertinmont is president.

PITTSBURGH—Fire, Feb. 17, destroyed a portion of the plant of the Walker Chemical Co., McCartney St., West End, with loss estimated at about $10,000.

CHESTER—The Scott Paper Co., foot of Market St., Philadelphia, Pa., has taken bids for the rebuilding of a 2-story factory at its works at Chester, 45 x 85 ft.

PITTSBURGH—The Creative Chemical Co. has filed plans for the erection of a new 1-story building at 4616-20 Friendship Ave.

HIGHSPIRE—The Keystone Carbonic Gas Co., recently organized, has acquired the local plant of the Highspir Distillery Co., for the establishment of a new plant for the manufacture of acid gas. The plant will be remodeled and improved, and a carbonic gas laboratory, totaling about 21,000 sq.ft. of floor area, constructed. S. S. Bailey is president, and E. W. Powell, secretary.

Tennessee

GREENBACK—The Greenback Brick Co. is planning for the erection of a new plant for the manufacture of brick and other burned clay products, with initial capacity of about 30,000 bricks per day. J. L. Jones is proprietor and general manager.

MT. PLEASANT—Fire, Feb. 23, destroyed the grinding plant of the Charleston Mining & Mfg. Co., with loss estimated at about $100,000, including machinery. It is planned to rebuild.

Texas

DALLAS—Fire, Feb. 20, destroyed a portion of the plant of the Hesse Envelope Co., Carter and Caruth Sts., manufacturer of paper products, with loss estimated at about $100,000, including machinery. George S. Otey is president.

Virginia

WOODSTOCK—The Hygrade Manganese Co., operating properties in the Cedar Creek Valley section, has taken out a state charter, with capital of $100,000, to provide for general expansion. The company will acquire lands to the extent of 3,000 acres and open up new properties as required. N. H. Manafee is president, and Charles B. Massie, vice-president.

West Virginia

NITRO—The Southern Dyestuffs Co. is planning for the installation of machinery in a number of buildings at its local plant for the manufacture of dyesuffs and intermediates. The extension will give employment to about 200 men.

KANAWHA CITY—The Libbey-Owens Sheet Glass Co. will make extensions and improvements in its plant at Kanawha City, to cost about $200,000, including a new power plant and other buildings.

New Companies

THE PYRALAC CHEMICAL CO., Newark, N. J., has been incorporated with a capital of $25,000, to manufacture chemicals and chemical byproducts. The incorporators are Ira Bingham, M. M. Fast and George N. Bick, 71 Paris St., Newark.

THE KEMO PRODUCTS CO., Rochester, N. Y., has been incorporated with a capital of $25,000, to manufacture chemicals and chemical byproducts. The incorporators are E. N. Barber, R. G. Fisher and S. E. Godden. The company is represented by Lynn Bros., attorneys, Rochester.

THE AMERICAN TIRE WORKS, INC., Pawtucket, R. I., has been incorporated with a capital of $50,000, to manufacture automobile tires and other rubber products. The incorporators are John T. Burke, D. and Nathan Siegelman, 50 Central Ave., Pawtucket.

THE SILVER FLASH OIL CO., 115 North Charles St., Baltimore, Md., has been incorporated with a capital of $100,000, to manufacture petroleum products. The incorporators are Otto C. Peterman, Silas Murray and Stanley C. Edmister.

THE CROWN FOUNDRY CO., Hersheel St., East Peoria, Ill., has been incorporated with a capital of $16,000, to manufacture iron, steel and other metal castings. The incorporators are Frank Barr, J. D. Armstrong and O. B. Slater.

THE NEW YORK COAL-TAR PRODUCTS & CHEMICAL CO., New York, N. Y., has been incorporated under Delaware laws with a capital of $1,000,000, to manufacture chemicals and affiliated products. The company is represented by the Corporation Guarantee & Trust Co., Land Title Bldg., Philadelphia, Pa.

THE KEYSTONE REFRACTORIES CO., Jersey City, N. J., has been incorporated with a capital of $10,000, to manufacture firebrick and other refractory products. The incorporators are J. W. Young, F. W. Beisman and L. E. Turk, 3 Foy Place, Jersey City.

THE SUNNYSIDE BRONZE FOUNDRY, New York, N. Y., has been incorporated with a capital of $5,000, to manufacture bronze and brass castings. The incorporators are K. Rippel, J. Forman and O. S. Berger. The company is represented by Abraham Lipton, 160 Broadway, New York.

THE TYCOON OIL CO., Erlanger, near Covington, Ky., has been incorporated with a capital of $50,000, to manufacture petroleum products. The incorporators are J. B. Respress, Erlanger; Benjamin Berkshire, Petersburg, Ky.; and E. B. Terrell, Covington, Ky.

THE ATLAS CHEMICAL LABORATORIES, INC., 1717 Mosher St., Baltimore, Md., has been incorporated with a capital of $50,000, to manufacture chemicals, acids, fertilizers and kindred products. The incorporators are B. L. Auld, John E. Auld, Sr., and Joseph Lichtenberg.

THE INDE-PENN OIL & REFINING CO., 223 North Galena Ave., Dixon, Ill., has been incorporated with a capital of $50,000, to manufacture petroleum products. The incorporators are Chester V. Chapman, Floyd D. Chapman and George F. Prescott.

THE ZENITH CHEMICAL CO., 285 South 20th St., Newark, N. J., has filed notice of organization to manufacture chemicals and chemical byproducts. The company is headed by Bernard W. VonSmuda, 343 16th Ave., Irvington, Newark.

THE LEVIN CO., 607 Nogalitos St., San Antonio, Tex., has been incorporated with a capital of $10,000, to manufacture lubricants and kindred oil products. Nathan Levin is president, and W. P. Gee, vice-president.

THE ACID-PROOF BRONZE CO., Pittsburgh, Pa., has been incorporated under Delaware laws, with capital of $200,000, to manufacture special bronze and other metal products. The incorporators are John P. and W. R. Kegg, and J. J. Elling, Pittsburgh. The company is represented by the Corporation Service Co., Wilmington, Del.

THE GREAT NORTHEASTERN CHEMICAL CO., 1362 Dorchester Ave., Boston, Mass., has filed notice of organization to manufacture chemicals and chemical byproducts. The company is headed by Richard Fine.

JAYNE & SIDEBOTTOM, New York, N. Y., have been incorporated with a capital of $10,000, to manufacture chemicals and kindred products. The incorporators are D. W. Jayne, H. G. Sidebottom and L. T. McManus. The company is represented by McKerchery & Link, 40 Rector St., New York.

THE TAYLOR-KENTUCKY OIL CO., 716 Fidelity Bldg., Baltimore, Md., has been incorporated with a capital of $750,000, to manufacture petroleum products. The incorporators are Morgan J. Cramer, Josiah and John R. Speer.

THE STAUDT & NEUMANN CO., 13 South Broadway, Aurora, Ill., has been incorporated with a capital of $36,000, to manufacture chemicals, chemical byproducts, drugs, etc. The incorporators are Louis C. and Albert J. Staudt, and Herbert L. Neumann.

THE METZ PLATINUM REFINING CO., 42 Walnut St., Newark, N. J., has filed notice of organization to manufacture refined metals. Werner P. Metz, 470 Belmont Ave., heads the company.

THE COMMONWEALTH DRUG & CHEMICAL CO., Philadelphia, Pa., has been incorporated under Delaware laws, with a capital of $100,000, to manufacture chemicals, chemical byproducts, drugs, etc. The incorporators are R. Lincoln and Hodge Lester, and H. L. Adams, Philadelphia. The company is represented by the Capital Trust Co. of Delaware, Dover, Del.

THE TRI-CITY BRICK CO., Second Ave. and 18th St., Rock Island, Ill., has been incorporated with a capital of $60,000, to manufacture brick, tile and other burned clay products. The incorporators are S. M. and J. L. Buckley, and H. O. Binyon.

THE RADIUM CHEMICAL CO., 44 Front St., Worcester, Mass., has filed notice of organization to manufacture chemicals and chemical byproducts. The company is headed by James W. Lecuyer and Frank S. Walker.

THE NEW JERSEY METAL TREATMENT CO., Newark, N. J., has been incorporated with a capital of $4,000, to manufacture special metals. The incorporators are Adolph Doll and Alexander Ross, 482 18th Ave., Newark.

THE QUAKER PAINT CO., Philadelphia, Pa., has been incorporated with a capital of $25,000, to manufacture paints, varnishes, etc. Ferdinand Ambacher, 1236 West Airdrie St., Philadelphia, is treasurer.

THE MODERN BRASS FOUNDRY CO., Indianapolis, Ind., has been incorporated with a capital of $25,000, to manufacture brass, bronze and aluminum castings. The incorporators are Fred W., Ralph N. and Pulaski E. Smith, all of Indianapolis.

THE K. I. HERMAN CHEMICAL CORP., 38 South Dearborn St., Chicago, Ill., has been incorporated with a capital of $300,000, to manufacture chemicals and chemical byproducts. The incorporators are K. I. Herman, R. E. Maurer and George J. Koreck.

THE PEERLESS CORK CO., 26 Prospect St., Newark, N. J., has filed notice of organization to manufacture cork products, seals, etc. The company is headed by Charles A. Hauser, 61 Linden Ave., Irvington, Newark.

THE LIBERTY COLOR & CHEMICAL CO., Philadelphia, Pa., has been organized to manufacture chemicals, chemical byproducts, dyes, etc. The incorporators are Thomas J. Grady, Thomas D. O'Brien and Robert J. Tracey. The company is represented by Charles A. Waters, 1208 Widener Bldg., Philadelphia.

THE ASSOCIATED REFINERIES CO., Denison, Tex., has been incorporated with a capital of $15,000, to manufacture petroleum products. The incorporators are V. H. Williams, M. R. Murray and George P. Blair, all of Denison.

HAYES-DEPRATO, INC., Ferndale, Mich., has been incorporated with a capital of $50,000, to manufacture paints, varnishes, etc. The incorporators are W. A. Wooliver, N. J. Deprato and W. P. Hayes, 6104 Crane Ave., Detroit, Mich.

THE PHOSPHO ALBUMEN CO., Newburgh, N. Y., has been incorporated with a capital of $30,000, to manufacture chemical specialties. The incorporators are R. H., J., and R. H. Cathcart, Jr., Newburgh. The company is represented by J. Witschief, attorney, Newburgh.

THE ROYALCROSS CO., Brooklyn, N. Y., has been incorporated with a capital of $50,000, to manufacture extracts, oils, etc. The incorporators are A. M. Wilson and M. Levine. The company is represented by J. B. Baer, 2 Rector St., New York.

THE FRAZIER CUSHION CORD TIRE CO., Wheeling, W. Va., has been incorporated with a capital of $75,000, to manufacture automobile tires and other rubber products. The incorporators are M. J. Cullinan and F. L. Schmidt, Wheeling; and Tuman Frazier, Martins Ferry, O.

THE OSCEOLA TURPENTINE CO., Deer Park, Fla., has been incorporated with a capital of $25,000, to manufacture turpentine and affiliated products. J. G. Henderson, Deer Park, is president; and J. H. Blount, secretary-treasurer, Jacksonville, Fla.

THE INDEPENDENT FLUORSPAR CO., Wilmington, Del., has been incorporated under state laws with a capital of $100,000, to operate fluorspar properties and produce commercial fluorspar. The company is represented by the Colonial Charter Co., Ford Bldg., Wilmington.

Capital Increases, etc.

THE DUFFNEY BRICK CO., Mechanicsville, N. Y., has filed notice of increase in capital to $110,000.

THE NEW EGYPTIAN PORTLAND CEMENT CO., Detroit, Mich., has filed notice of increase in capital from $500,000 to $1,000,000.

THE LIBERTY CHEMICAL WORKS, 352 East Illinois St., Chicago, Ill., has filed notice of increase in capital from $20,000 to $30,000.

THE MUSKOGEE VITRIFIED BRICK CO., Muskogee, Okla., has filed notice of increase in capital from $100,000 to $125,000. F. C. Nicholson is president.

THE ALUMNADA LEAD CO., Warren, Ariz., has filed notice of increase in capital from $1,000,000 to $1,300,000.

THE WEIRTON STEEL CO., Wierton, W. Va., has arranged for a bond issue of $1,000,000, for general operations and financing. E. T. Weir is president.

THE MORTON SALT CO., 80 East Jackson Blvd., Chicago, Ill., has filed notice of increase from $5,200,000 to $6,200,000.

CORD A. MYER, Tarrytown, N. Y., manufacturer of cement, has filed a voluntary petition in bankruptcy with liabilities stated at $257,315.

The plant of the ZIRCONIUM CO. OF AMERICA, Monument and 11th Sts., Baltimore, Md., manufacturer of metal products, has been acquired at a receiver's sale by William T. Larkin.

C. W. Johnson has been appointed receiver for the AETNA REFINING CO., Louisville, Ky., operating an oil refinery.

THE SUTHERLAND PAPER CO., Kalamazoo, Mich., has filed notice of increase in capital from $1,000,000 to $1,500,000.

Coming Meetings and Events

AMERICAN CHEMICAL SOCIETY will hold its spring meeting at Birmingham, Ala., April 4 to 7, 1922.

AMERICAN ELECTROCHEMICAL SOCIETY will hold its spring meeting in Baltimore, April 27, 28 and 29, 1922. Headquarters will be at the Emerson Hotel.

AMERICAN FOUNDRYMEN'S ASSOCIATION will hold its next convention and exhibit at Rochester, N. Y., during the week of June 5, 1922. Meetings will be held in the spring instead of in the fall as heretofore

AMERICAN INSTITUTE OF CHEMICAL ENGINEERS will hold its summer meeting at Niagara Falls, June 19 to 22. Headquarters will be at the Clifton Hotel.

AMERICAN SOCIETY FOR STEEL TREATING will hold a sectional meeting at the Bureau of Mines auditorium, Pittsburgh, Pa., on May 25 and 26. The International Steel Exposition and Convention of the society will be held in the General Motors Bldg., Detroit, Mich., Oct. 2 to 7.

AMERICAN SOCIETY FOR TESTING MATERIALS will hold its twenty-fifth annual meeting June 26 to July 1, at Atlantic City, N. J. Headquarters will be at the Chalfonte-Haddon Hall Hotel.

INTERNATIONAL UNION OF PURE AND APPLIED CHEMISTRY will hold a meeting at Lyons, France, June 27 to 30.

IRON AND STEEL INSTITUTE (British) will hold its annual meeting on May 4 and 5 at the House of the Institution of Civil Engineers, Great George St., S. W., 1, London.

NEW JERSEY CHEMICAL SOCIETY holds a meeting at Stetters Restaurant, 842 Broad St., Newark, N. J., the second Monday of every month.

STAMFORD CHEMICAL SOCIETY, Stamford, Conn., holds a meeting in the lecture room of the local high school on the fourth Monday of each month, except June, July, August and September.

The following meetings are scheduled to be held in Rumford Hall, the Chemists Club, New York: March 10—American Chemical Society; March 24—Society of Chemical Industry, regular meeting; April 21—Society of Chemical Industry (in charge), American Electrochemical Society, Société de Chimie Industrielle, American Chemical Society, joint meeting; May 5—American Chemical Society, regular meeting; May 12—Société de Chimie Industrielle (in charge), American Chemical Society, Society of Chemical Industry, American Electrochemical Society, joint meeting; May 19—Society of Chemical Industry, regular meeting: June 9—American Chemical Society, regular meeting.